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NAVIGATION CHANNEL IMPROVEMENT, GASTINEAU CHANNEL, ALASKA; HYDRAULIC MODEL INVESTIGATION

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Prepared for:

Army Engineer District, Alaska

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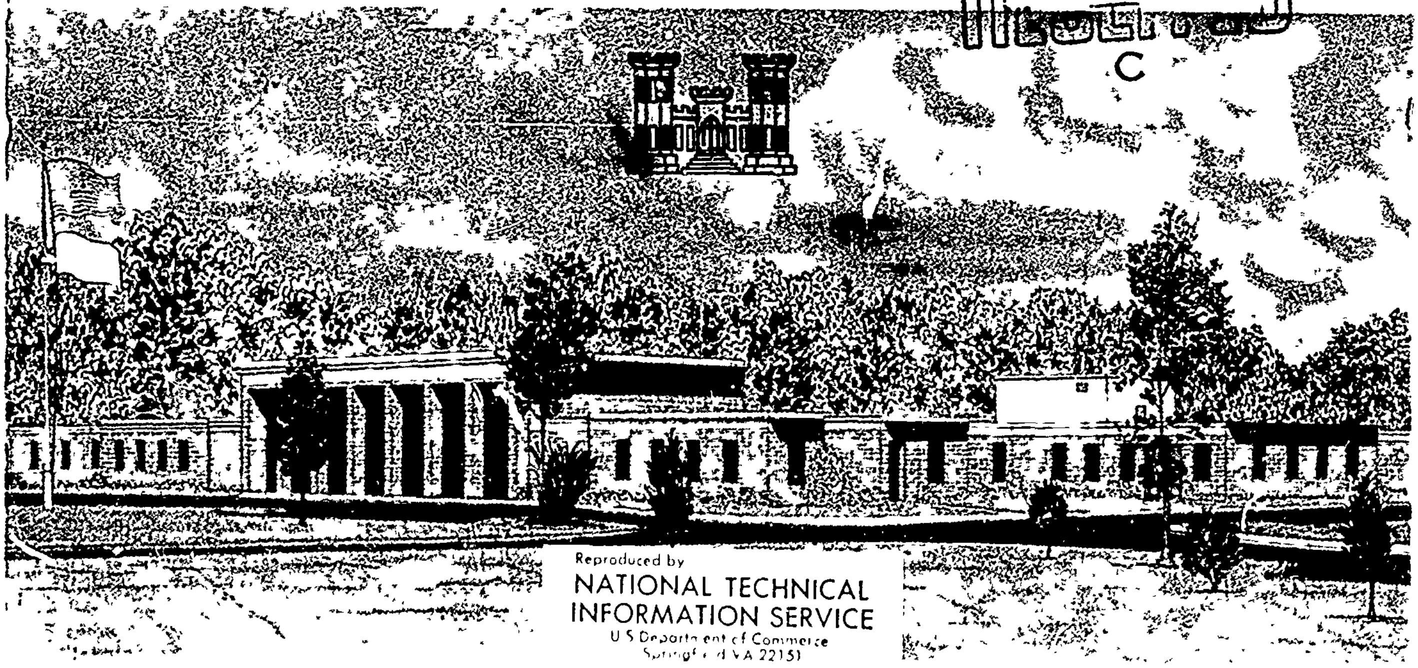
NAVIGATION CHANNEL IMPROVEMENT GASTINEAU CHANNEL, ALASKA

Hydraulic Model Investigation

by

F. A. Herrmann, Jr.



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13. ABSTRACT

The existing Federal project through the Gastineau Channel, Alaska, provides for a navigation channel 4 ft deep at mllw (including overdepth dredging) with a bottom width of 75 ft. The channel was constructed in 1959-60 through an area with a prevailing bottom elevation of +10 to +15 ft mllw and soon experienced rapid shoaling at several locations. No maintenance dredging has been performed, primarily because of the large cost of moving a dredge to this remote area. A model study was conducted to determine the best means of resolving the shoaling problem. The model, constructed to linear scale ratios of 1:500 horizontally and 1:100 vertically, reproduced about 7 miles of Gastineau Channel from Fritz Cove on the west to 1 mile north of Juneau, Alaska, on the east. It was equipped to reproduce and study prototype tides, tidal currents, fresh-water inflow, and shoaling. The shoaling tests were conducted using granulated plastic to simulate the natural sediments, and a technique was developed to properly reproduce the prototype shoaling pattern and distribution. It was determined from the model tests that any one of several impermeable dikes with a top elevation above high water and located along the north side of the navigation channel would reduce shoaling by 80 to 85 percent. Diversion of Fish Creek away from the navigation channel would result in an additional 5 percent reduction. The shortest dike tested (plan 4) was 17,250 ft long, and the shoaling reduction for this plan was essentially the same as that for longer dikes.

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FOREWORD

A request was made by the U. S. Army Engineer District, Alaska, on 1 April 1963 to conduct a hydraulic model study of Gastineau Channel, Alaska, and the request was subsequently approved by the Chief of Engineers. Field surveys for the study were made in the summer and fall of 1963, and the model study was conducted during the period October 1964-May 1967.

The model investigation was conducted in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. E. P. Fortson, Jr. (retired), Chief of the Hydraulics Laboratory; G. B. Fenwick (retired), Assistant Chief of the Hydraulics Laboratory; H. B. Simmons, present Chief of the Hydraulics Laboratory; and F. A. Herrmann, Jr., Chief of the Estuaries Branch. The tests were conducted by Mr. Herrmann, assisted by Mr. D. A. Crouse. This report was prepared by Mr. Herrmann.

Directors of WES during the course of this investigation and the preparation and publication of this report were COL Alex G. Sutton, Jr., CE; COL John R. Oswalt, Jr., CE; COL Levi A. Brown, CE; and COL Ernest D. Peixotto, CE. Technical Directors were Messrs. J. B. Tiffany and F. R. Brown.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
feet per second	0.3048	meters per second
cubic feet per second	0.02831685	cubic meters per second
square feet	0.092903	square meters
square miles	2.58999	square kilometers

SUMMARY

The existing Federal project through the Gastineau Channel, Alaska, provides for a navigation channel 4 ft deep at mllw (including overdepth dredging) with a bottom width of 75 ft. The channel was constructed in 1959-60 through an area with a prevailing bottom elevation of +10 to +15 ft mllw and soon experienced rapid shoaling at several locations. No maintenance dredging has been performed, primarily because of the large cost of moving a dredge to this remote area. A model study was conducted to determine the best means of resolving the shoaling problem.

The model, constructed to linear scale ratios of 1:500 horizontally and 1:100 vertically, reproduced about 7 miles of Gastineau Channel from Fritz Cove on the west to 1 mile north of Juneau, Alaska, on the east. It was equipped to reproduce and study prototype tides, tidal currents, freshwater inflow, and shoaling. The shoaling tests were conducted using granulated plastic to simulate the natural sediments, and a technique was developed to properly reproduce the prototype shoaling pattern and distribution.

It was determined from the model tests that any one of several impermeable dikes with a top elevation above high water and located along the north side of the navigation channel would reduce shoaling by 80 to 85 percent. Diversion of Fish Creek away from the navigation channel would result in an additional 5 percent reduction. The shortest dike tested (plan 4) was 17,250 ft long, and the shoaling reduction for this plan was essentially the same as that for longer dikes.

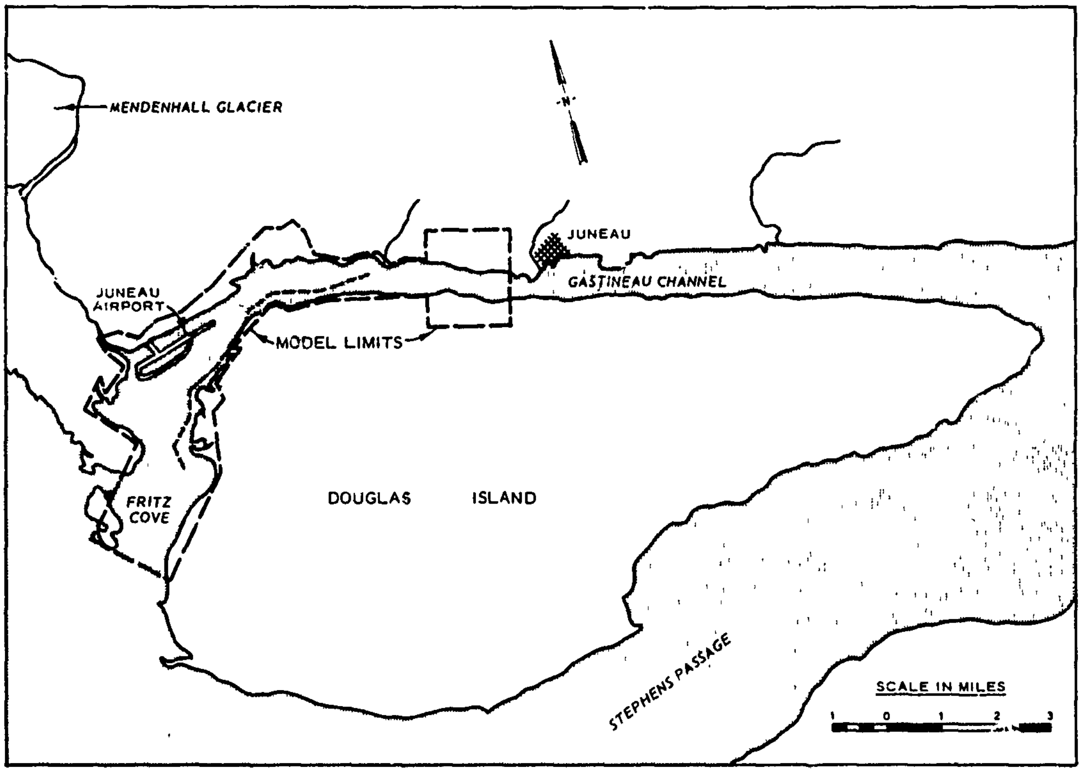

Fig. 1. Location map

NAVIGATION CHANNEL IMPROVEMENT

GASTINEAU CHANNEL, ALASKA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

Description of the area

1. Gastineau Channel (fig. 1), a narrow strait about 16 miles* long that separates Douglas Island from the mainland of southeastern Alaska, connects Stephens Passage on the east with Fritz Cove on the west. Juneau, Alaska, is located on the mainland side of the channel at about its midpoint. East of Juneau the channel is fairly uniform with the width varying from 4000 to 6000 ft. A naturally deep channel, with controlling depth of about -45 ft at mean lower low water (mllw), exists in this portion of Gastineau Channel. West of Juneau the width varies from about 2000 ft near Juneau to about 10,000 ft near the western end of the channel.

2. The western 5.5 miles of the channel has been described as a giant shoal and has a general elevation of +10 to +15 ft mllw. The shoal is roughly centered on the meeting point of the tides that enter the opposite ends of the channel. Since the tides are very closely equal in range and phase, tidal velocities in this area are almost zero. Therefore, it is not surprising that sediments carried into the area by tributary streams are not moved out of the shoal area. The shoal consists primarily of glacial till with the surface layers being mainly fine to coarse sands covered by a thin layer of organic muck.

Existing navigation project

3. Gastineau Channel provides a 15-mile shortcut for boats

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* A table of factors for converting British units of measurement to metric units is presented on page vii.

traveling north from Juneau. In the past, however, the controlling depth across the shoal area was about +15 ft mllw so that it could only be navigated by small boats and only at high tide. In 1945, Congress authorized construction of a navigation channel through the shoal area of the channel with a bottom width of 75 ft, a depth of 0 ft mllw, and 1-on-3 side slopes. The project was actually constructed during 1959-60 to a depth of -4 ft mllw, including 2 ft of overdepth dredging and 2 ft of advance maintenance dredging. The dredge spoil was placed in spoil banks along the north side of the navigation channel, as shown in fig. 2.

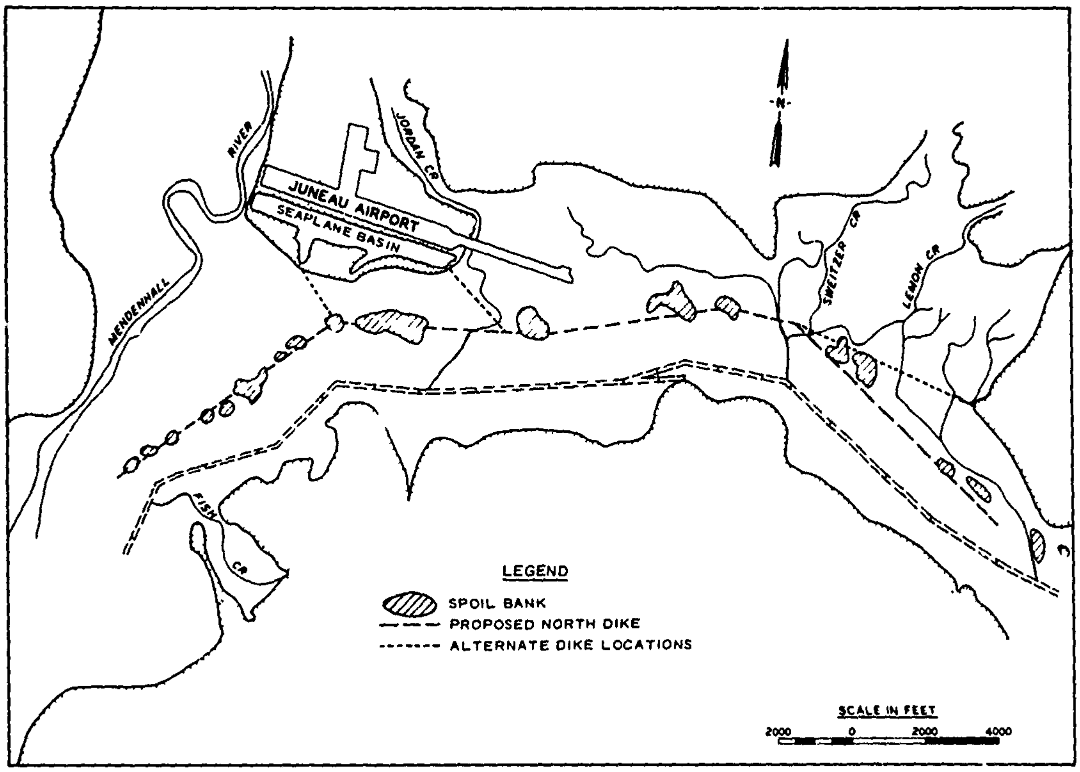

Fig. 2. Spoil bank locations and proposed dike locations

4. Subsequent to construction of the navigation channel, rapid shoaling occurred within the limits of the project. The primary reasons for this rapid shoaling appear to be twofold. First, it has been determined that under the influence of tidal action the natural side slopes are between 1 on 6 and 1 on 10, rather than 1 on 3 as constructed.

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Therefore, extensive sloughing of the side slopes was experienced during the first year subsequent to construction of the project. Second, the navigation channel produced a dredge cut that was as much as 15 ft below the elevation of the adjacent tidal flats, which created a drainage canal for the tidal flats. This situation increased the hydraulic gradients of the natural channels across the shoal area, thus producing higher velocities that are capable of moving large quantities of sediment into the canal. The result of this action is especially evident at the mouths of the tributary streams and sloughs entering the navigation channel. No maintenance dredging has been undertaken, primarily because no dredges are available in Alaska.

5. The Juneau Airport and seaplane basin are located on the edge of the tidal flats north of the navigation channel. When the navigation channel was first dredged, there was a sizable breach in the east end of the seaplane basin dike. Under this condition, almost the entire volume of the seaplane basin drained into Jordan Creek during ebb tide phases, resulting in the flushing of large amounts of sediment out of Jordan Creek into the navigation channel. The breach in the dike was subsequently repaired, and apparently navigation channel shoaling in the vicinity of Jordan Creek has been significantly reduced.

Hydraulic characteristics

6. The channel is subject to tidal action at both ends. The tides display a diurnal inequality typical of the Pacific Ocean. The mean tide range at Juneau is 14.0 ft; however, the mean diurnal range (from mhhw to mllw) is 16.6 ft. The extreme tidal range is about 26.5 ft, and the extreme high-water elevation is +21.1 ft mllw.

7. Several freshwater streams enter the channel--the largest of these is the Mendenhall River, which enters the channel at its extreme western end near the Juneau Airport. The mean and maximum discharges of this stream are 1100 and 10,000 cfs, respectively. Other streams entering the system include Sheep, Gold, Salmon, Lemon, Sweitzer, and Fish Creeks. Of these, only Lemon Creek has an appreciable flow with mean and maximum discharges of 220 and 3000 cfs, respectively.

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Salinity characteristics

8. Prototype salinity data obtained in September 1963 indicate that there is no appreciable salinity gradient, surface to bottom, during the flood phase of the tide. During the later stages of the ebb tide, surface salinities are considerably lower than bottom salinities in the navigation channel. During these stages of the ebb tide, almost the entire tidal prism of the area is confined to the navigation channel. Since fresh water from tributary streams enters the navigation channel, and since current velocities are not sufficient to create appreciable vertical mixing, it is not surprising that this salinity gradient exists during the ebb flows. It is believed that the density effects resulting from vertical salinity differences are not significant to hydraulic or shoaling phenomena in the problem area.

Purpose of the Model Study

9. In June 1961, the U. S. Army Engineer District, Alaska, requested that the Corps of Engineers Committee on Tidal Hydraulics review the shoaling problem and recommend measures which might resolve the problem. At that time, the Committee recommended that more extensive field surveys be made in order to study the problem in more detail and made several generalized recommendations for reducing channel shoaling.

10. In June 1962, the Alaska District again requested that the Committee review the Gastineau Channel problem. With the more detailed information the Alaska District was able to furnish at that time, the Committee published a report entitled "Navigation Project in Gastineau Channel, Alaska" which listed several specific alternate solutions to the problem as follows: (a) redredge the channel periodically, (b) reduce velocities over the shoal areas with dikes or by reshaping natural contours, (c) localize scouring velocities to paved or enrocked areas so that no bed movement occurs, (d) construct settling basins to trap the sediments, (e) divert tributary streams and sloughs away from the navigation channel, and/or (f) isolate the navigation channel from the tidal flats by means of a continuous dike.

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11. Of these possible solutions, the Committee recommended isolation of the navigation channel by means of a continuous dike as being the only one giving promise of a permanent improvement. The north dike proposed by the Committee (fig. 2) would be open at both ends to preserve the tidal conditions north of the dike. It seemed probable that rather sizable volumes of sediment would be carried out of the tidal flats past the ends of the dike; however, because of the abrupt termination of the shoal at both ends, it was not believed that the sediments would be transported around the ends of the dike and into the navigation channel. Much of the material required for construction of the dike would logically be obtained by deepening and widening the navigation channel. This would lead to increased navigation benefits from the project and would satisfy requests of local interests for an enlarged channel. It was believed that an additional benefit which might be realized from this plan would be the reclamation of land for future development. Several alternate dike alignments are also presented in fig. 2.

12. The Committee further recommended that a hydraulic model study of the problem be undertaken with the following purposes: (a) to study the present current patterns over the shoal area as a guide to laying out improvement works; (b) to determine the velocities associated with any proposed dike construction, weir construction, or channel diversion; and (c) to study dike closure procedures in the event that a land reclamation project is considered in the improvement program. Subsequently, item (c) was removed from the program, and the model study was expanded to include an investigation of shoaling distribution patterns with and without improvement works. The study was further expanded to include investigation of the effects of enlarging the dimensions of the navigation channel.

PART II: THE MODEL

Description

13. The Gastineau Channel model reproduced about 7 miles of the Gastineau Channel from Fritz Cove to about 1 mile north of Juneau, an area of about 15 square miles. Each end of the model terminated in a headbay of suitable area and depth for installation and operation of a tide generator. The limits of the area reproduced are shown in fig. 3, and a general view of the model is shown in fig. 4.

14. The model was constructed to linear scale ratios, model to prototype, of 1:500 horizontally and 1:100 vertically. From these basic ratios the following scale relations were computed according to the Froudian relations: slope 5:1, velocity 1:10, time 1:50, discharge 1:500,000, and volume 1:25,000,000. Salinity was not reproduced in the model, since an analysis of prototype salinity data indicated that density phenomena had no significant effects on shoaling. One prototype tidal cycle (diurnal) of 24 hr and 50 min was reproduced in the model in 29 min and 48.5 sec. Horizontal control was based on the Universal Transverse Mercator grid system, Zone 8, and vertical control was based on mllw, 1959 revision, USC&GS. The model was approximately 65 ft long and 25 ft wide, covered an area of about 1600 sq ft, and was of fixed-bed construction; it was completely enclosed to protect it and its appurtenances from the weather and to permit uninterrupted operation. The navigation channel was molded in removable blocks so that desired alterations could readily be made as necessary to investigate changes in channel dimensions.

15. The permanent roughness employed consisted of 1/2-in.-wide metal strips, although it was subsequently determined that the concrete bed of the model was sufficiently rough to eliminate the need for any additional roughness.

Appurtenances

16. The model was equipped with the necessary appurtenances to

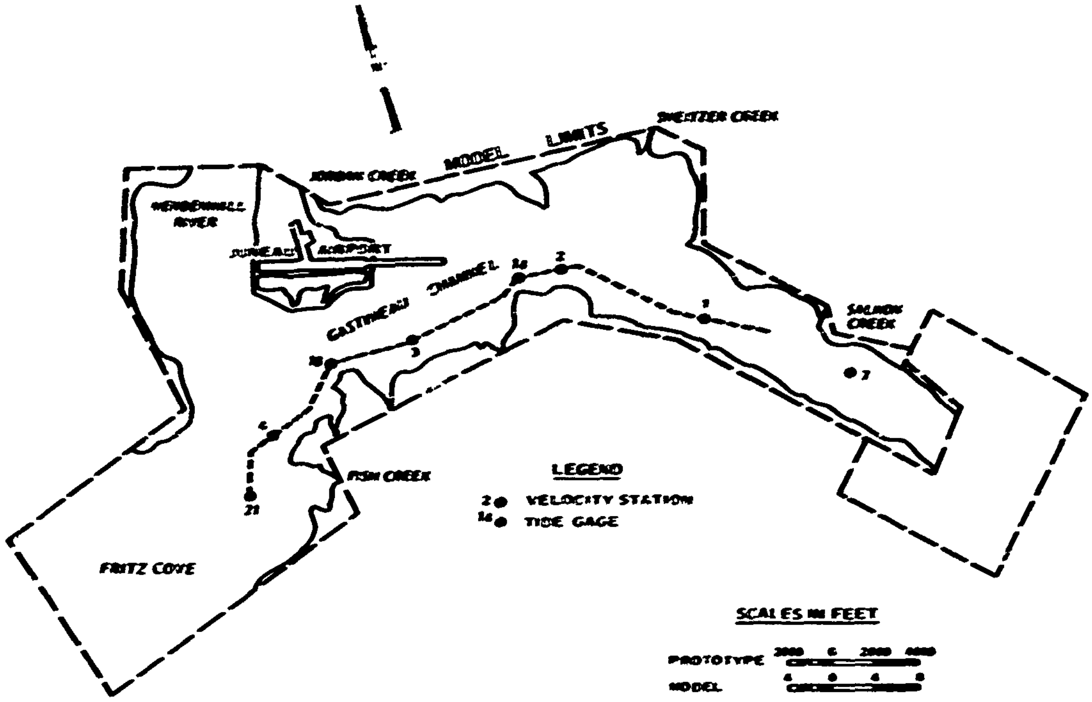

Fig. 3. Model layout

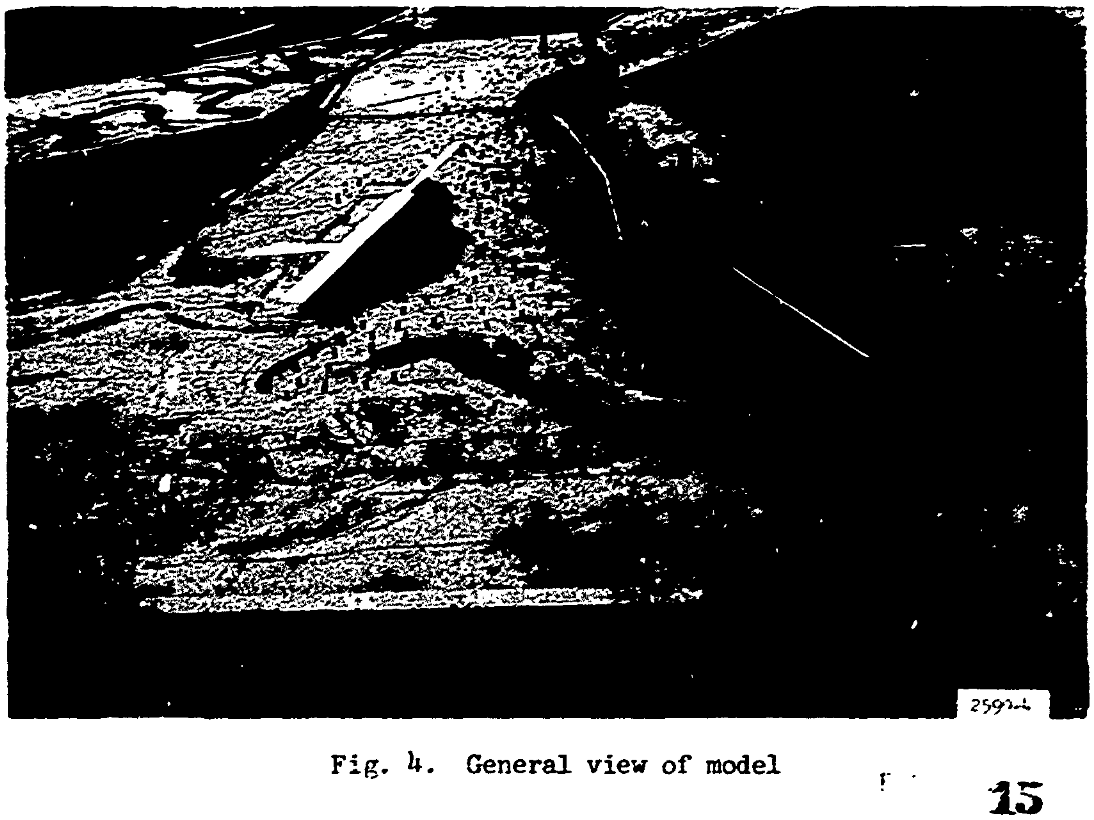

Fig. 4. General view of model

reproduce and measure all pertinent phenomena such as tidal elevations, current velocities, freshwater inflow, dispersion characteristics, and shoaling distribution. Apparatus used in connection with the reproduction and measurement of these phenomena included two primary tide generators and recorders, tide gages, current velocity meters, freshwater inflow measuring weirs, skimming and measuring weirs, dye injection equipment, and shoaling recovery apparatus. This equipment is described in detail in subsequent paragraphs.

Tide generators and recorders

17. The reproduction of tidal action in the model was accomplished by means of tide generators located in the headbays at each end of the model. These tide generators maintained a differential between a pumped inflow of water to the model and a gravity return flow to the supply sump as required to reproduce all characteristics of the prototype tides at the control stations (tide gages 7 and 21 shown in fig. 3). The tide generators were equipped with continuous tide recorders so that the accuracy of model tide reproduction could be checked visually at any time. The control element of one of the tide generators and its tide recorder are shown in photo 1, while one of the automatic valves in the outfall line is shown in photo 2. A schematic diagram of the tide generation system is shown in fig. 5.

Tide gages

18. Permanently mounted point gages (photo 3) were installed at the locations of the four recording tide gages used for collection of field tide data (fig. 3). The model gages were graduated in 0.001 ft (0.1 ft prototype) and were used to measure tidal elevations throughout the model. Portable point gages were used to measure tidal elevations at other points as required.

Current velocity meters

19. Current velocity measurements were made in the model with miniature Price-type current meters (photo 4). The meter cups were about 0.04 ft in diameter, representing 4.0 ft in the prototype. The center of the cups was about 0.045 ft from the bottom of the frame, representing 4.5 ft in the prototype. The meters were calibrated frequently

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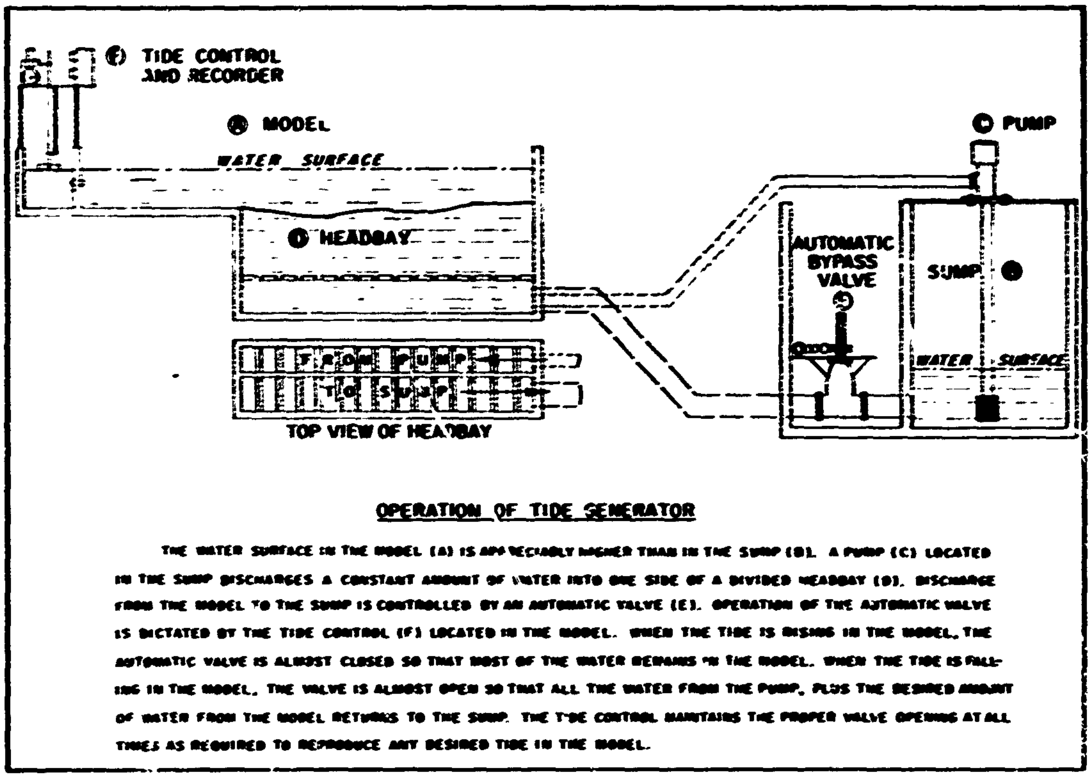

Fig. 5. Schematic diagram of tide generation system

to ensure their accuracy and were capable of measuring velocities as low as about 0.05 fps (0.5 fps prototype). For water depths less than about 5 ft, velocities were determined by timing the movement of surface floats over a known distance.

Freshwater inflow measuring weirs

20. Van Leer (or California-pipe) weirs (shown in photo 5 with constant head tank) were used to obtain precise measurements of the freshwater inflows of Mendenhall River and Lemon Creek. No freshwater inflow was reproduced in the other tributary creeks, since their flows were insignificant.

Skimming and measuring weirs

21. The water that accumulated in the model as a result of the Mendenhall River and Lemon Creek inflows had to be removed in order to maintain a constant volume of water in the model. This was accomplished by means of a floating skimming weir (photo 6) that removed a quantity

of water equal to the freshwater inflows to the model. Measurement of the discharge over the skimming weir was made with a Van Leer weir.

Dye injection equipment

22. Dye tracer tests were conducted to determine areas of Gastineau Channel affected by freshwater flows of Mendenhall River and Lemon Creek. The dye was introduced directly into the outfall pipe of the freshwater Van Leer weirs of the tributaries. Dye dispersion patterns were recorded photographically, but no measurements of dye concentration were made.

Shoaling recovery apparatus

23. Shoaling was reproduced in the model by injecting granulated polystyrene plastics. Known volumes of the shoaling material were hand-placed at predetermined locations in the model before and during each shoaling test. At the end of the model test, the shoaling material deposited within the limits of the navigation channel was recovered by suction using a flared nozzle connected by hose to an aspirator (or hydraulic ejector) (photo 7); the material was then measured volumetrically.

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PART III: VERIFICATION OF THE MODEL

24. It should be emphasized that the worth of any model study is wholly dependent upon the proven ability of the model to produce with a reasonable degree of accuracy the results which can be expected to occur in the prototype under given conditions. It is essential, therefore, before any model tests are undertaken of proposed improvement plans, that the required similitude first be established between the model and prototype and that all scale relations between the two be determined.

25. Verification of the Gastineau Channel model was accomplished in two phases: (a) hydraulic verification, which ensured that tidal elevations and times, and current velocities and directions were in proper agreement with the prototype; and (b) shoaling verification, which assured acceptable reproduction of prototype shoaling distribution.

26. The accurate reproduction of hydraulic, salinity, and shoaling phenomena in an estuary model is an important phase in the preparation of the model for its ultimate use in evaluating the effects of proposed improvement works. In this instance, it was decided that salinity effects played an insignificant role in the shoaling problem; therefore, salinity was not reproduced in this model. Verification of hydraulic phenomena for one spring tide and one mean tide required a series of elaborate tests extending over a period of four months. Shoaling verification of the model required an additional three months. Prototype data used for the hydraulic verification were published by the U. S. Department of the Interior, Geological Survey, Water Resources Division, Juneau, Alaska, in a report of October 1963 entitled "Gastineau Channel Study--Administrative Report."

Hydraulic Verification

Prototype data

27. Prototype data collected for verification of the model included: (a) continuously recorded tidal elevations at four locations (fig. 3); (b) current velocity, current direction, and salinity

observations at three depths at each of four stations in the navigation channel (fig. 3); (c) hydrographs of freshwater tributaries in the problem area; and (d) hydrographic and topographic surveys. The field data for items (a), (b), and (c) were gathered in September 1963 by the Juneau, Alaska, office of the U. S. Geological Survey. These prototype data were obtained over a 12-day period during which the tides varied from spring range to slightly less than mean range. Freshwater inflows during the metering period were somewhat higher than the average annual high discharge.

28. Current velocity and salinity data were obtained using only one survey boat, which was anchored at each station in succession for periods of 25 hr. This procedure was repeated so that velocity observations were made at each station on three different days in the 12-day metering period. Since the tide range was varying rather rapidly during this period, the velocities obtained at any one station were not directly comparable to those at any other station. Velocity and salinity sampling stations were located only along the center line of the navigation channel because the surrounding tidal flats are exposed throughout the major portion of the tidal cycle.

<u>Tidal adjustment</u>

29. The objective of the model tidal adjustment was to obtain an accurate reproduction of prototype tidal elevations and phases throughout the model. Prototype tidal data from four recording tide gages (fig. 3) were available to verify the accuracy of the model tidal adjustment. These gages recorded continuously throughout the 12-day period of prototype velocity and salinity measurements.

30. During the prototype metering period, there were significant variations of tidal range and other tidal characteristics. In order to avoid the time-consuming and expensive procedure of adjusting the model to reproduce all 12 tides observed during the metering period, it was decided to select two 24.84-hr (diurnal) tides representative of spring and mean tide conditions occurring within the 12-day period and to complete the adjustment of tides and currents throughout the model for only the two tides thus selected. The two tides chosen were 4-5 September

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1963 (spring tide) and 9-10 September 1963 (mean tide).

31. The normal procedure followed for tidal adjustment is to adjust the tide generator to accurately reproduce the desired tide at the control tide gage, then to adjust the model roughness until prototype tidal elevations and times are properly reproduced at all tide gages throughout the model. Since the Gastineau Channel model had a tide generator at either end of the model, the procedure was somewhat more complicated. First, a nodal point of tidal currents from the opposite ends of the channel was determined from examination of the prototype current velocity data and the general hydrography; a barrier was then constructed across the model at that location, thus isolating the influence of the tide generators from each other. In this way it was possible to adjust each tide generator individually to approximately reproduce the proper tides at their respective control tide gages. After this was accomplished, the barrier was removed and the tide generators were simultaneously adjusted to reproduce the proper tides at the control gages. Because of the interaction between the tides generated at either end of the model, it was necessary to adjust the roughness throughout the model concurrently with the adjustment of the tide generators.

32. Comparisons of model and prototype tidal elevations at tide gages 7, 14, 18, and 21 for the two tides reproduced in the model are shown in plates 1-4. The maximum discrepancy in high-water elevations was ± 0.3 ft prototype (0.003 ft model), whereas at low water the model water-surface elevation was as much as 1.4 ft prototype (0.014 ft model) too high. These large discrepancies in low-water elevations occurred only at the interior tide gages (14 and 18) for spring tide conditions. The water depths in the channel at low water for the spring tide became so shallow in the model that surface tension effects probably became large enough to retard the outflow, thus holding up the low-water elevation. Velocities in the channel during these phases of the tide were so low in both model and prototype that the overall effect of the large discrepancies in low-water elevations was not significant to the hydraulic or shoaling regimens of the channel. Maximum discrepancy in the times of high and low was about 1/4 hr prototype (18 sec model).

Adjustment of currents

33. The objective of the model current adjustment was to obtain an accurate reproduction of the vertical and longitudinal distribution of prototype currents throughout the model. Because the flow is confined to the narrow navigation channel throughout most of the tidal cycle, it was not practical to meter prototype velocities outside the channel. Thus, it was not possible to determine the lateral distribution of prototype currents.

34. Prototype current velocity observations were made at the four stations shown in fig. 3. The velocity measurements were made with a Price-type current meter, while current direction was determined by observing the deflection of a light weight suspended on a thin fishing line at the same depth at which the velocity measurement was being made. Readings were made at half-hour intervals at 1 ft below the surface, middepth, and 1 ft above the bottom for periods of 25 hr at each station. It must be pointed out that because tidal currents enter Gastineau Channel from both ends the absolute directions of ebb (or flood) currents are opposite at the two ends of the channel. It was determined that the nodal point is in the immediate vicinity of sta 2; thus, ebb currents at sta 1 are directed toward Juneau (east), whereas ebb currents at sta 3 and 4 are directed toward Fritz Cove (west). Apparently the nodal point moves back and forth past sta 2, since it was determined that ebb currents (falling tide) can actually move either east or west. A similar situation exists for flood currents. Therefore, in the plates showing velocity measurements, the current directions at sta 2 are specified as either east or west instead of ebb or flood; currents at sta 2 that flow east are usually ebb currents.

35. The procedure followed for adjustment of current velocities was to reproduce the two tidal conditions (spring and mean) in turn and adjust the model roughness until the distribution and velocity of currents at the metering stations were correctly reproduced in the model. During this phase of the model verification it was determined that all artificial roughness in the model could be removed.

36. As discussed previously, the center of the cups on the model

velocity meters was 4.5 ft (prototype) above the bottom of the frame. Thus, bottom velocities obtained in the model using these meters actually represent conditions 4.5 ft (prototype) above the channel bottom, whereas prototype bottom velocities were obtained 1 ft above the channel bottom. When the top of the meter cups became exposed above the water surface, it was no longer possible to accurately measure velocities with the meter. Because of the dimensions of the velocity meters, it was not possible to measure velocity with these meters in depths of water less than about 5.0 ft. When the depth at a station dropped below 5.0 ft, it was necessary to measure the current velocity by timing the movement of a surface float over a known distance. Because of the shallow depths involved when measuring velocity with the surface floats, the measurements thus obtained are presented as the surface, middepth, and bottom velocities.

37. Prototype velocity observations for the spring tide period were made on 3-7 September 1963, but only the tide of 4-5 September was reproduced in the model. Similarly, velocities during the mean tide period were observed on 7-11 September 1963, but only the tide of 9-10 September was reproduced in the model. The tides occurring during the entire metering period at gage 7 are shown in fig. 6 to indicate the rapid change in tidal range that was observed. Because of this rapid change in tidal range, it is obvious that current velocities observed on any particular day are not representative of the velocities which would have been observed at the same station on any other day, even the preceding or following day. Thus, it was necessary to adjust the prototype velocity measurements so that they would more nearly represent prototype conditions on the two days reproduced in the model. It was found that a reasonably good linear relation existed between tidal range and maximum velocity. However, it was necessary to develop separate relations for each current direction, observation depth, and station. Equations for the lines of best fit for the data were determined using a simple regression analysis of the least-squares method. Tidal range was taken as the independent variable, and maximum velocity was taken as the dependent variable. For all the curves developed, the average standard

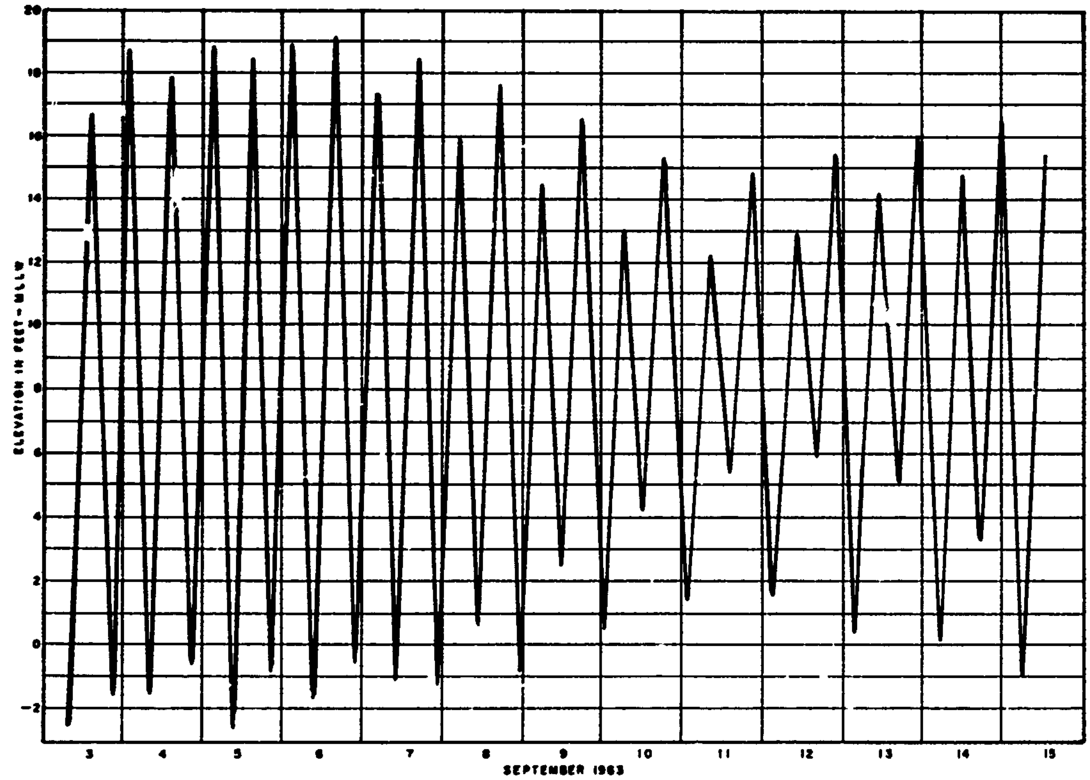

Fig. 6. Prototype tides at gage 7

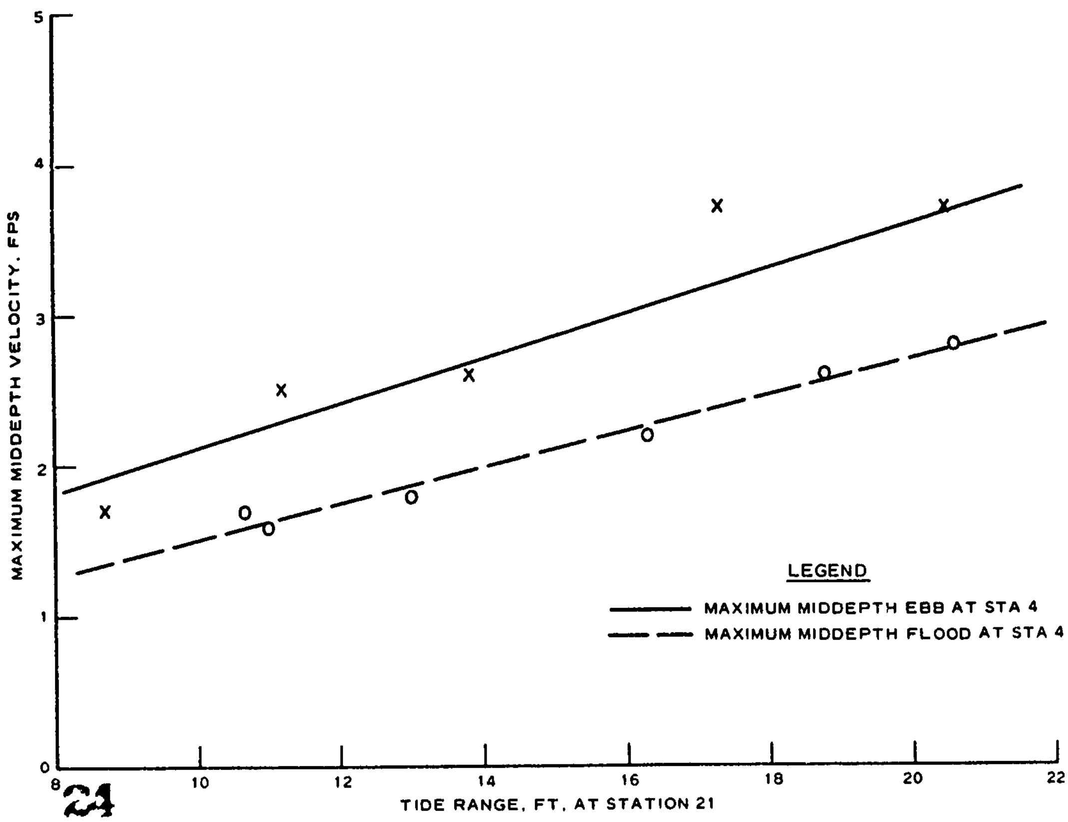

Fig. 7. Typical tide/velocity correlation curves

error of estimate was about 0.2 fps. A typical pair of the correlation curves is presented in fig. 7.

38. Comparisons of model and prototype current velocities for the four stations are presented in plates 5-12. In each of these plates the date of the tide reproduced in the model and the date of the actual prototype velocity measurement are shown. It must be remembered, however, that the prototype data have been adjusted to represent conditions of the tide reproduced in the model. Half-hour measurements were plotted for both model and prototype, and smooth curves were drawn through the points. The model velocities at sta 4 are generally too high. It is believed that the model was too rough in that general area; this would result in higher flows in deep areas which are less affected by boundary roughness than are shallow areas. In other words, the excess roughness reduced flows over the shallow tidal flats and increased flows in the deeper navigation channel. The navigation channel was too small to offset the slow imbalance by adding roughness strips within the limits of the confined channel, and it was not practical to attempt to reduce the roughness of the concrete model bed. Thus, there was no practical method for effecting an accurate reproduction of velocities at sta 4. With this one exception, the agreement between model and prototype current measurements was considered to be satisfactory.

Shoaling Verification

Prototype data

39. Unfortunately, the only prototype shoaling data available consisted of three sets of 17 cross sections of the channel, the locations shown in fig. 8, surveyed immediately after completion of dredging (1960) and again in 1961 and 1962, along with one comprehensive hydrographic survey of the area made in 1963. The volume of shoaling within the navigation channel between cross sections was determined on an end-area basis and converted to a percentage of the total shoaling in the channel in order to determine the shoaling distribution pattern. Thus, only an approximate determination of the prototype shoaling characteristics was possible.

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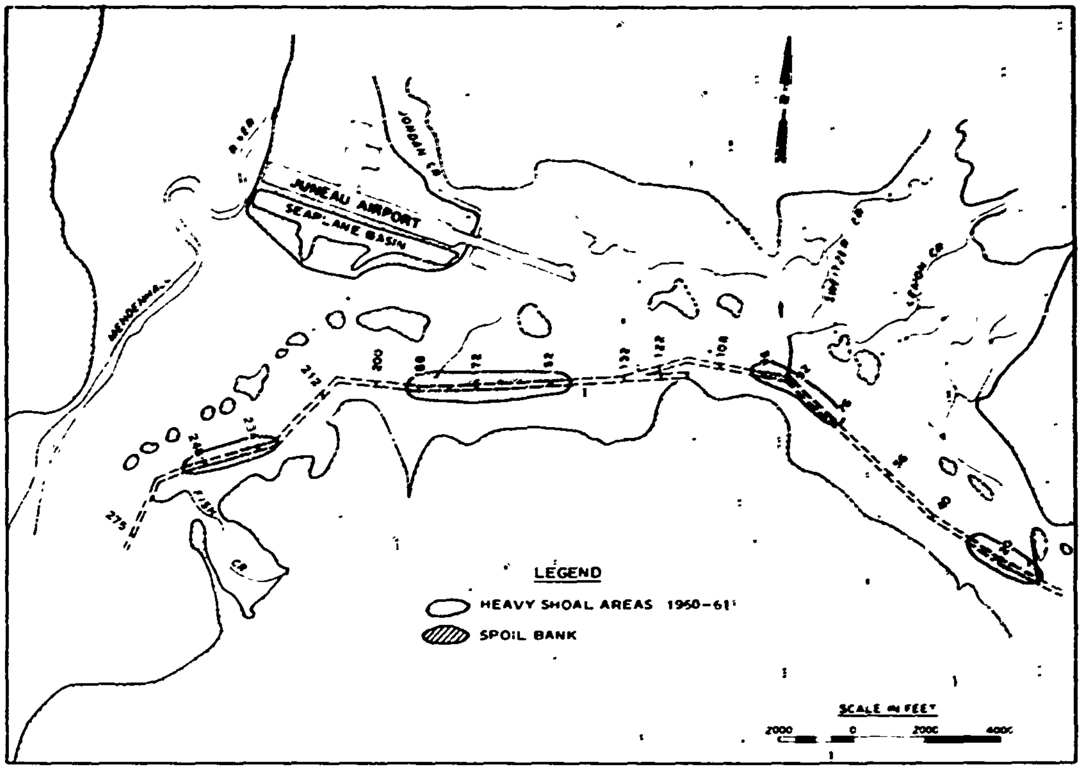

Fig. 8. Location of cross sections and heavy shoal areas (1960-61)

40. Examination of the available shoaling data indicates that heavy shoaling occurred during the first year after dredging (1960-61) at four locations (fig. 8) as follows:

a. Sta 20. This shoaling near the eastern end of the channel is believed to have been caused by severe side sloughing.

b. Sta 76-96. Sweitzer and Lemon Creeks enter the channel in this reach. Severe erosion (not sloughing) of the side slopes was observed in this area. The heaviest shoaling was observed in the northerly portion of the channel, with the deep water in the channel shifting south.

c. Sta 152-188. Jordan Creek enters the channel in this reach. Severe erosion and sloughing of the side slopes were observed. The breach in the seaplane basin dike at the Juneau Airport accentuated this shoaling, and a tidal slough entering the channel from the south between sta 152 and 172 may have increased shoaling at the eastern end of this reach.

d. Sta 234-248. Several tidal sloughs enter the channel in this reach. Severe sloughing and erosion of the side slopes were observed. The dredge spoil disposal areas

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in this area were closer to the channel than for the rest of the project; therefore, it is possible that this shoaling was accentuated by the return of dredged material to the channel.

41. In the period 1961-63, the shoaling pattern in these areas was changed as follows:

a. Sta 20. Only very light shoaling occurred, probably because of stabilization of the side slopes.

b. Sta 76-96. Very light shoaling occurred in the vicinity of the main freshwater inflow (sta 94). Moderate to heavy shoaling was shifted as far east as sta 40 and as far west as sta 108.

c. Sta 152-188. Very light shoaling occurred in the vicinity of the mouth of Jordan Creek (sta 180). The breach in the seaplane dike was repaired in November 1962, thus reducing the supply of sediment to this area. Heavy shoaling occurred as far east as sta 132 and as far west as sta 234. Erosion of side slopes was apparently still occurring but not sloughing.

d. Sta 234-248. Only very light shoaling occurred, probably attributable to stabilization of side slopes. The heavy shoaling areas during this period are shown in fig. 9.

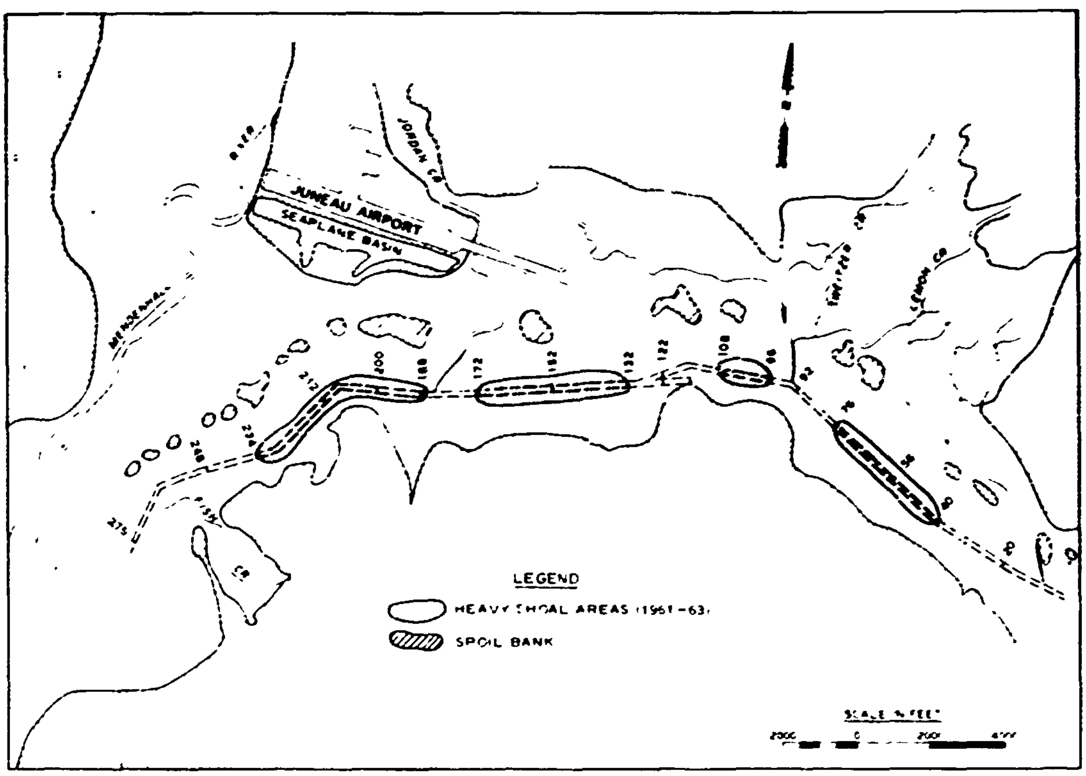

Fig. 9. Location of heavy shoal areas (1961-63)

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42. It thus appears that within one year after construction of the navigation channel the channel side slopes had become relatively stable, so that subsequent channel shoaling includes only a minor amount of side sloughing. The shoaling that occurred during 1961-63 was used as the representative prototype shoaling condition. The volume of shoaling between each cross section was converted into a percentage of the total shoaling within the navigation channel, and the resulting shoaling distribution pattern is shown in plate 13. For the purpose of the model shoaling verification, the navigation channel in the model was molded to conform to 1961 conditions.

Shoaling test procedure

43. The initial phase of the model shoaling verification was the determination of the dispersion characteristics of the freshwater flows of Mendenhall River and Lemon Creek. This was accomplished by introducing dye with the discharge of each stream and observing its spread throughout the model for several tidal cycles. In this manner it was possible to determine the areas affected by any suspended sediments that might be carried by these streams. Dye diffusion patterns were recorded photographically at times of high- and low-water slacks for conditions of the spring tide combined with mean and high freshwater discharges. These tests indicated that only a very small portion of the Mendenhall River discharge eventually makes its way into the navigation channel. On the other hand, the Lemon Creek discharge rapidly dispersed throughout the entire length of the navigation channel. As a result of these dye dispersion tests, it was concluded that the Mendenhall River is not a major source of sediments to the navigation channel, but the small tributary creeks might supply significant volumes of sediment to the channel.

44. The model shoaling verification involved the reproduction of the prototype shoaling distribution pattern throughout the length of the dredged navigation channel. The basic objective of the model shoaling verification was to identify a synthetic sediment which would move and deposit under the influence of the model forces in the same manner that the natural sediments move and deposit under the influence of the

natural forces. In the process of identifying a suitable sediment for use in the model, a great number of variables were involved and each had to be resolved by trial and error in the model. The most significant variables include: (a) shape, size, gradation, and specific gravity of the artificial sediment; (b) method, location, duration, and quantity of artificial sediment injection; (c) rate of freshwater discharge; (d) magnitude of tide; (e) length of model operation; and (f) readjustment of model roughness. Model water temperature must be closely monitored, since similar shoaling tests run with different water temperatures often give significantly different results.

45. For the model shoaling tests, granulated polystyrene with a specific gravity of 1.08 and a mean grain size of 0.8 mm was selected as best approximating the action of the prototype sediment. A rather complex operating technique was developed. Before the start of a shoaling test, 6000 cc of the model sediment was placed on the bed of the model in the lower portion of Sweitzer Creek in the general vicinity of channel sta 90. During the test, additional material was added periodically at Sweitzer Creek, Jordan Creek, Fish Creek, and near gage 18. A total of 55,000 cc was used for each test. The amounts and times of these injections are presented in table 1, while the locations of the injection areas are shown in fig. 10. The model was operated for 7.5 tidal cycles using the spring tide and the following tributary inflows: Mendenhall River, 3000 cfs; Lemon Creek, 1000 cfs; Fish Creek, 300 cfs; and Sweitzer Creek, 75 cfs. Locations of the shoaling sections with reference to the channel stations are shown in fig. 11. At the conclusion of each test, the material deposited between cross sections within the navigation channel was picked up with a suction device and measured volumetrically. The shoaling distribution was then computed as the percentage of total material recovered from each section. The model technique was exactly the same for all tests, except as noted later for tests involving impermeable dikes through the injection areas. Results of the shoaling verification are presented in table 2 and plate 13. The accuracy with which the model duplicated the prototype shoaling distribution pattern was considered quite sufficient to ensure a valid indication of

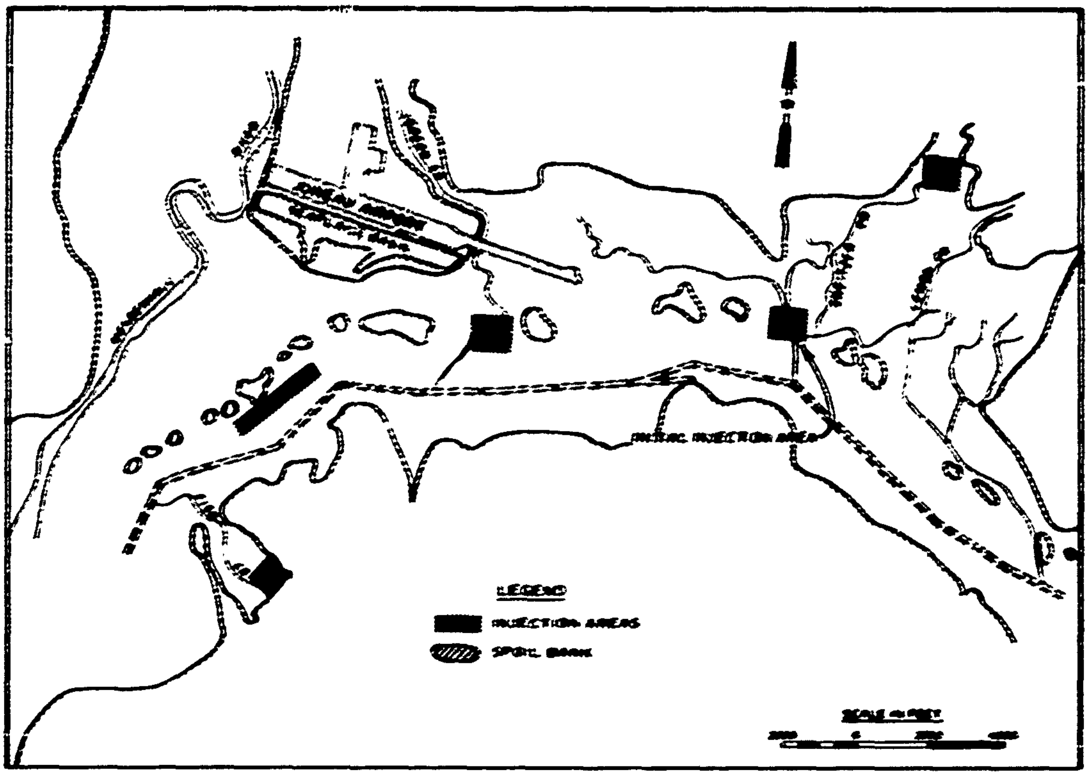

Fig. 10. Location of injection areas for shoaling tests

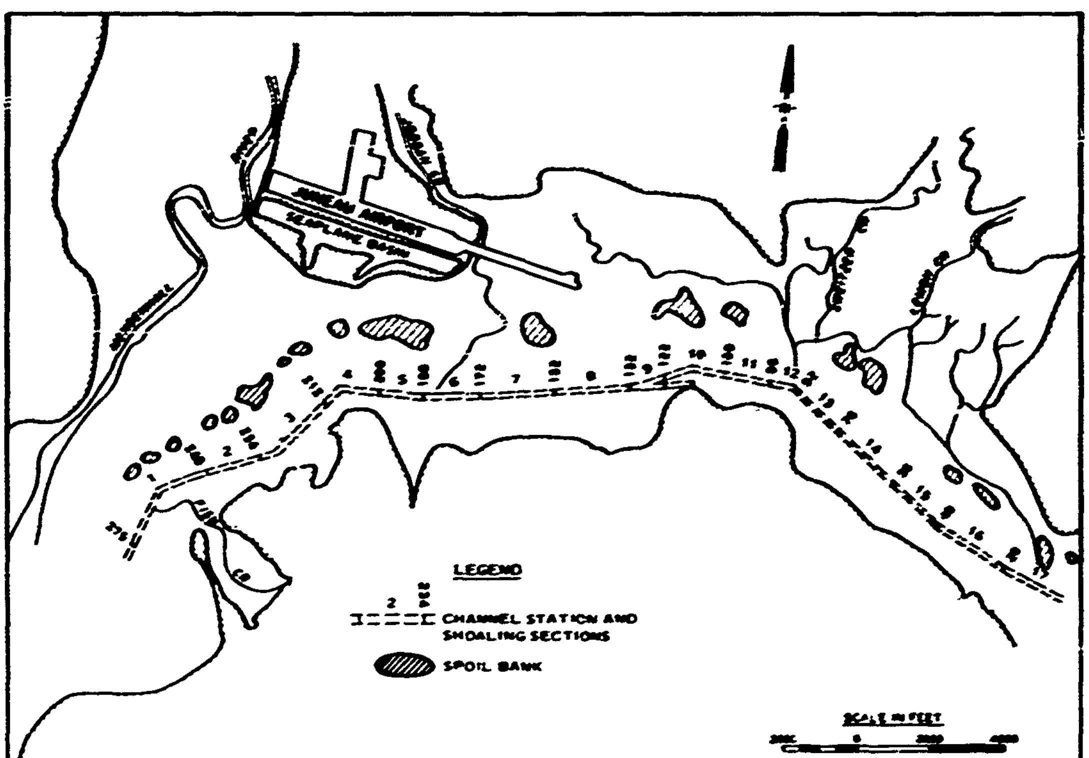

Fig. 11. Location of shoaling sections

the effects of the proposed improvement plans on shoaling characteristics in the problem area. The shoaling time scale determined from this verification test was 7.7 hr model = 25 months prototype, or roughly 1:2300.

Limitations of the Accuracy of Model Measurements

46. Measurements of tidal elevation in the model were made with point gages graduated to 0.001 ft, or 0.1 ft prototype. Since the error between model and prototype tidal data was of approximately this order of magnitude, the model measurements of tidal elevations are considered accurate and satisfactory.

47. The limitations of the current velocity meters used in the model should be considered in making close comparisons between model and prototype velocity data. The center line of the meter cup was 0.045 ft above the bottom of the frame; therefore, bottom velocity measurements in the model using the meters were actually obtained at a point 4.5 ft (prototype) above the bottom, instead of 1.0 ft as in the prototype metering program. Surface velocities were measured in the model with the cups just barely submerged. Since the cups were about 0.04 ft high, surface velocities in the model using the meters were obtained at a point between 2 and 3 ft below the surface instead of 1.0 ft as in the prototype metering survey. Conversely, surface velocities in the model measured with floats were actually on the surface. The model velocities were determined by counting the number of revolutions of the meter cups in a 10-sec interval (which represented a period of about 8 min prototype) as compared with about a 1-min observation in the prototype. The horizontal spread of the entire cup wheel was about 0.11 ft (55 ft prototype) as compared with less than 1.0 ft for the prototype meter. Thus, the distortion of areas (model to prototype) results in comparison of prototype point velocities with model mean velocities for a much larger area. The same is true for the vertical area, since the height of the meter cups was about 0.04 ft (4.0 ft prototype) as compared with only a few inches for the prototype meter.

The accuracy of the model velocity meter is about ±0.50 fps (prototype) in the lower velocity ranges and about ±0.25 fps (prototype) in the higher velocity ranges.

48. In fixed-bed shoaling tests, it is not possible to reproduce bed and bank scour. Thus bank erosion, bank sloughing, new scour holes, etc., are not reproduced in the model. Should any of these particular phenomena occur in the prototype, they would create a source of new sediments, which could cause a significant increase in channel shoaling. The accuracy of the model shoaling tests is considered to be about ±10 percent, since that is the limit of the accuracy of repeating identical tests.

Discussion of Results of Verification Tests

49. Agreement between model and prototype phenomena, as evidenced by the results of hydraulic and shoaling verification data, appeared to be excellent. The model was considered to be sufficiently similar to its prototype that it could be used with confidence in quantitative studies of the effects of proposed improvement plans on hydraulic phenomena and would be reasonably reliable in determining qualitative effects with regard to shoaling phenomena.

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PART IV: TESTS AND RESULTS

Test Conditions

50. As a basis for determining the changes to be expected as a result of constructing improvement works and/or enlarging the navigation channel, information was required on the hydraulic and shoaling characteristics of the conditions investigated. Consequently, measurements of tidal elevations and surface and subsurface velocities, observations of surface current patterns, and identical shoaling tests were made for each condition tested.

51. All tests were made for conditions of the spring tide of 4-5 September 1963 (plates 1 and 2), which had a diurnal range of 20.6 ft. The tributary inflows were as follows: Mendenhall River, 3000 cfs; Lemon Creek, 1000 cfs; Fish Creek, 300 cfs; and Sweitzer Creek, 75 cfs. The model was operated with fresh water only, since analysis of prototype data indicated that saltwater-generated density currents have no significant effect on the hydraulic or shoaling phenomena of the area. Except for the navigation channel, the model was molded to conform to 1963 prototype hydrography. During the testing phase of the model study, the navigation channel was molded to the design condition being investigated.

Types of Data Obtained

52. Hydraulic data obtained consisted of tidal elevations measured at half-hour (prototype) intervals; current velocities obtained at half-hour (prototype) intervals at 3 ft below the surface, middepth, and 5 ft above the bottom; and surface current patterns recorded by means of photographs taken at hourly (prototype) intervals. Velocity measurements were made at sta 1-4, which were all located along the center line of the navigation channel. Shoaling tests were made to determine both the rate and distribution pattern of shoaling in the navigation channel.

53. Surface current patterns were photographed throughout the

tidal cycle. The photographs were time-lapse exposures of confetti floating on the water surface. A bright light was flashed immediately before the camera lens was closed, resulting in a bright spot at approximately the end of each confetti streak which indicates the direction of flow. Current velocities can be determined by measuring the lengths of confetti streaks and comparing the lengths with the velocity scales provided in the photographs. In addition to surface current patterns, the waterline is also shown in the photographs. Surface current photographs taken at hourly intervals for each condition tested were furnished the Alaska District, but only selected photographs of each condition are included in this report.

Conditions Tested

54. It was assumed that any improvement plan actually constructed in the prototype would include redredging the navigation channel to design conditions. Thus, for the base test condition the channel was molded to design conditions (4 ft deep by 75 ft wide). By conducting a shoaling test of this base condition, it was possible to determine the shoaling rate and distribution pattern in the design channel without the effects of side sloughing. The four improvement plans tested with the existing navigation channel consisted of variations of the impermeable north dike proposed by the Committee on Tidal Hydraulics. These plans are shown in fig. 12. Plan 1 consisted of a 26,850-ft-long dike. The plan 2 dike was 24,350 ft long, having been shortened by 2500 ft on the Juneau end. For plan 3, the dike of plan 2 was shortened by 5000 ft on the Fritz Cove end, resulting in a 19,350-ft-long dike. For plan 4, the dike of plan 3 was shortened an additional 2100 ft on the Fritz Cove end, resulting in a 17,250-ft-long dike, and Fish Creek was diverted from the navigation channel directly into Fritz Cove. The best plan tested (plan 4) was then tested with two possible enlarged navigation channels. Plan 5 consisted of a 12-ft-deep by 150-ft-wide channel with no supplemental improvements, while plan 6 consisted of the same channel with proposed improvements of plan 4. Plan 7 consisted of a 30-ft-deep

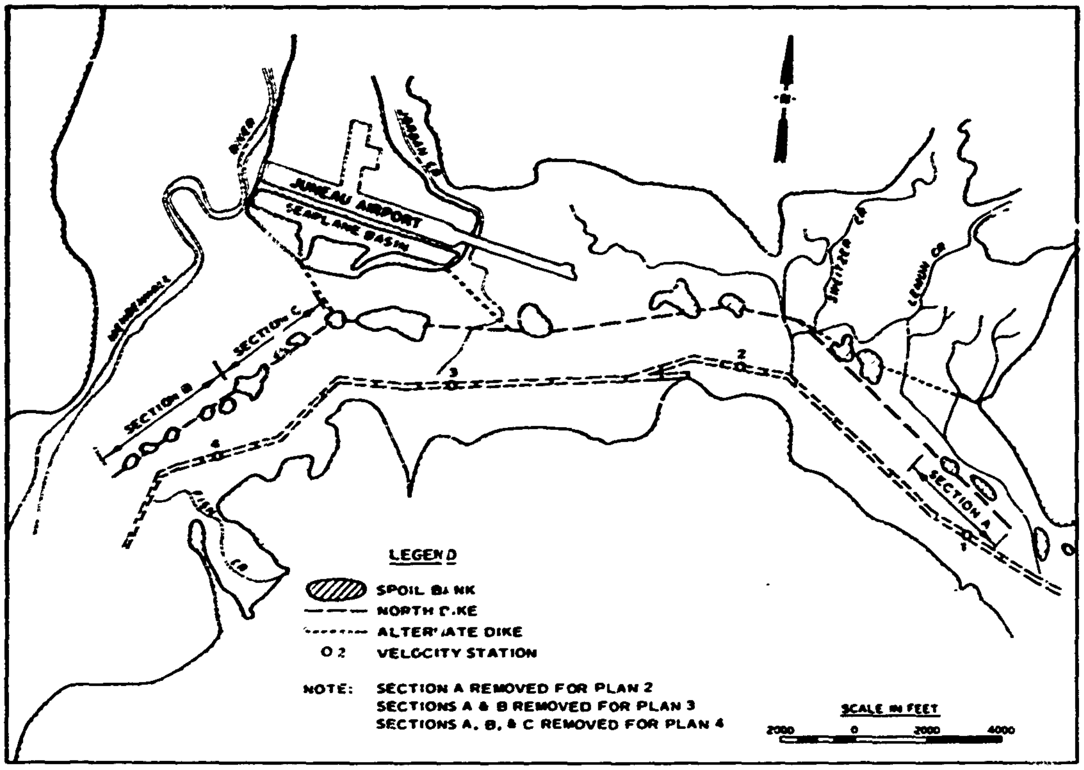

Fig. 12. Elements of proposed north dike plans 1-4

by 300-ft-wide channel with no supplemental improvements, while plan 8 consisted of the same channel with the proposed improvements of plan 4.

Base Test

55. Base test conditions were essentially the same as those for hydraulic and shoaling verification, except that the navigation channel was molded to the original design dimensions of 4 ft deep and 75 ft wide. A comparison of the profiles of these two channel conditions is shown in fig. 13. The average deepening over the entire length of the navigation channel was 4.5 ft. However, between sta 1 and 2 and between sta 3 and 4 the average deepening was 5.9 ft.

56. The shoaling index, which appears at the bottom of tables 2, 3, 5, 7, and 8, is defined as the total amount of material recovered for a test, divided by the total amount of material in some different test to which the former is to be referenced. Thus, the shoaling index for any

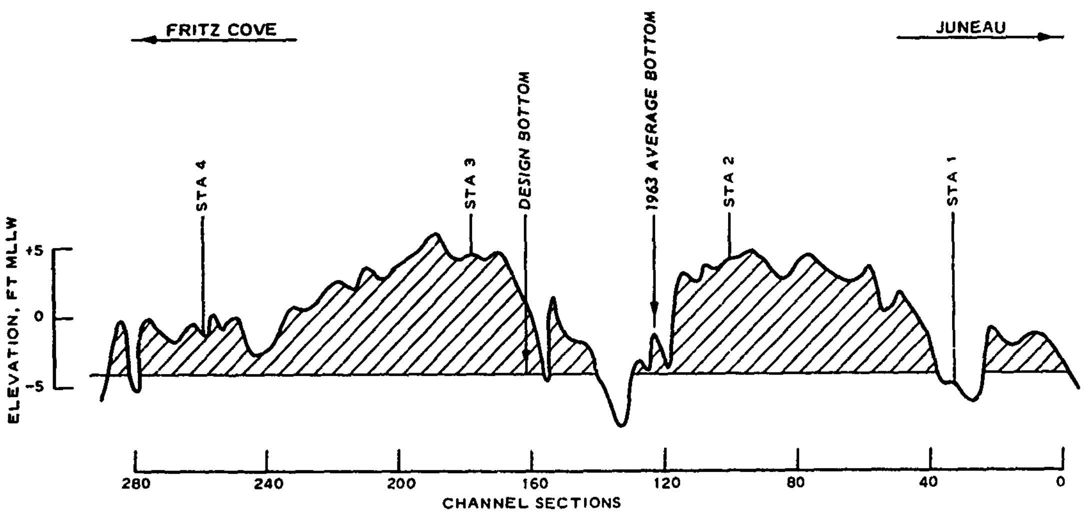

Fig. 13. Channel bottom profiles, design and 1963 conditions

test, as compared with existing conditions, can be determined by dividing the total amount of material recovered for that test by the total amount recovered for the shoaling verification test. An index greater than 100 percent indicates an increase in shoaling as a result of the condition tested; conversely, an index less than 100 percent indicates that the condition tested would reduce shoaling. Changes on the order of plus or minus 10 percent are considered to be within the limits of accuracy of repeating identical tests and thus are not considered significant.

57. The results of the shoaling base test are presented in table 2 and plate 14. The shoaling rate for the base test was 43.5 percent greater than that observed in the shoaling verification, and the areas experiencing the greatest increases were sections 6 and 10-14. Jordan Creek enters the channel in section 6, and Sweitzer Creek enters in the center of sections 10-14. The latter area also brackets the nodal point of the tidal currents.

58. Tidal elevations measured during the base test are compared with those of the model verification in plates 15 and 16. The tides at sta 7 and 21, which were located near each end of the model, were not greatly affected by the changed channel conditions. At sta 7, the elevations of the high and low waters were decreased by about 0.1 to 0.3 ft.

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At sta 21, the time phasing of the base test tide was generally about 10 to 15 min earlier than that of the verification tide, the elevation of higher low water was decreased by about 0.3 ft, and the elevation of higher high water was increased by about 0.3 ft. However, at the gages located near the center of the model (sta 14 and 18), the shape of the tide curves was considerably altered because deepening the channel allowed the low-water elevations at these stations to decrease by 3.5 to 6.5 ft.

59. Comparisons of the verification and base test velocities at sta 1-4 are presented in plates 17-20. Maximum ebb velocities were increased by 0.75 to 1.50 fps at sta 1 and were reduced by 0.25 to 1.25 fps at sta 3 and 4. Maximum east (generally ebb) velocities at sta 2 were increased by 1.0 to 1.75 fps. Maximum flood velocities were increased by 1.0 to 2.0 fps at sta 1 and 4 and were reduced by 0.75 to 1.0 fps at sta 3. Maximum west (generally flood) velocities at sta 2 were reduced by 0.75 to 1.0 fps. During the base test, and in all subsequent tests, the location of sta 2 was moved to a point 1000 ft (prototype) west of its original position (fig. 14). This was done to avoid the center of the large eddy formation in the immediate vicinity of the original location of sta 2. Surface current patterns at hourly intervals throughout the tidal cycle are shown in photos 8-32.

Dike Tests

60. Plans 1-4 consisted primarily of impermeable dikes with a top elevation of about +25 ft mllw situated on the alignment proposed by the Committee on Tidal Hydraulics. This alignment varied from about 500 to 1500 ft north of the navigation channel and incorporated the spoil banks created during construction of the navigation channel. The dikes of plans 1-4 varied in length from 26,850 to 17,250 ft and are shown in fig. 12. It was decided by the Alaska District not to investigate any of the proposed alternate dike layouts. These alternate dikes were to have been connected to the existing bankline for the purpose of land reclamation behind the dike. During the shoaling tests of the various

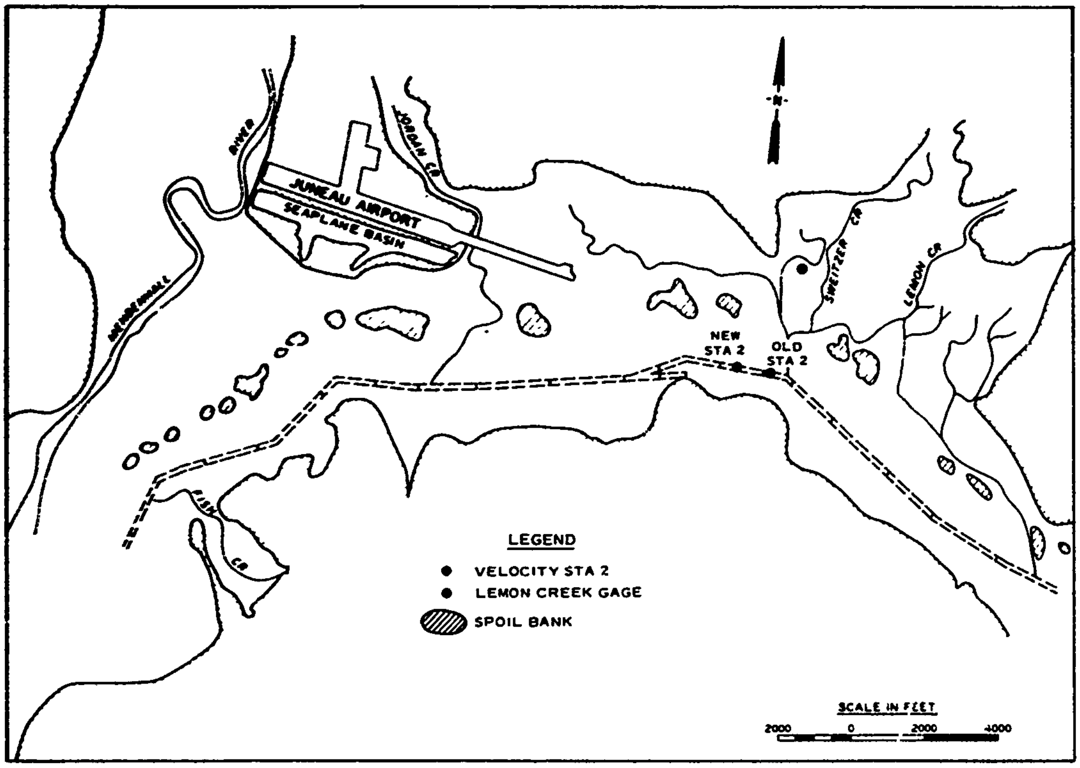

Fig. 14. Revised location of velocity sta 2 and location of Lemon Creek tide gage

dike plans, sediment placed in the model at the initial injection area and the Jordan Creek injection area (see fig. 10) was divided so that half the material injected in each of these areas was placed on each side of the dike. This was done to ensure that a supply of sediment would be available to the navigation channel even though the dike separated the channel from the major portion of the tidal flats.

Plan 1

61. Plan 1 consisted of a 26,850-ft-long dike as shown in fig. 12. The results of the shoaling test, presented in table 3 and plate 21, show that the plan 1 dike caused a reduction in channel shoaling of 83.2 percent.

62. Tidal observations for plan 1 are presented in plates 22-24. A new tide gage location was established in the Lemon Creek area behind the dike (fig. 14) to determine the effects of the proposed dikes on tidal action in that vicinity. Tidal elevations throughout the entire

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tidal cycle were not significantly affected at sta 7, nor were the high-water elevations at the other gages throughout the model; however, the low-water elevations at the other stations in the navigation channel (sta 14, 18, and 21) were increased by 0.4 to 0.7 ft and at the Lemon Creek gage by 3.2 ft. The measurements at the Lemon Creek gage indicate that extensive areas behind the dike will remain flooded at the time of low water, instead of completely draining into the navigation channel as occurs for existing conditions. Velocity observations are presented in plates 25-28. Maximum ebb velocities at all three depths at sta 1 were decreased by 0.5 to 1.0 fps, and maximum east velocities were increased by 1.0 to 1.5 fps at middepth and bottom at sta 2. No significant changes in velocity were observed at sta 3 and 4.

63. Photos 33 and 34 (surface current patterns) were taken at the time of higher high water (hhw) and lower low water (llw), while photos 35 and 36 are most representative of strength of ebb and strength of flood conditions. Comparison of photo 33 with photo 22 shows that plan 1 did not cause any significant change in the waterline at hhw. On the other hand, comparison of photos 34 and 28 shows that plan 1 will cause extensive areas behind the dike to remain flooded at the time of llw. Seven areas were determined throughout the model which might be subject to the most significant changes in velocity as a result of the dike plans and are shown in fig. 15. Maximum surface velocities within each of these areas, but outside the navigation channel, are presented in table 4. Velocities in areas that were constricted by the dike (areas 1, 3, and 5) were significantly higher for plan 1 than for the base test. Furthermore, the region of highest velocity in area 1 was much closer to the bankline for plan 1 than for the base test. Conversely, velocities were generally reduced between the dike and Douglas Island (areas 2, 4, and 6). Velocities between the dike and Mendenhall Peninsula (area 7) were unchanged. Photo 37 shows the crosscurrents that developed along the navigation channel during the flood phase of tide in area 4 and at the east end of the dike. On the other hand, the existing crosscurrents at the mouth of Sweitzer Creek (as shown in photos 8 and 11) were essentially eliminated by the dike.

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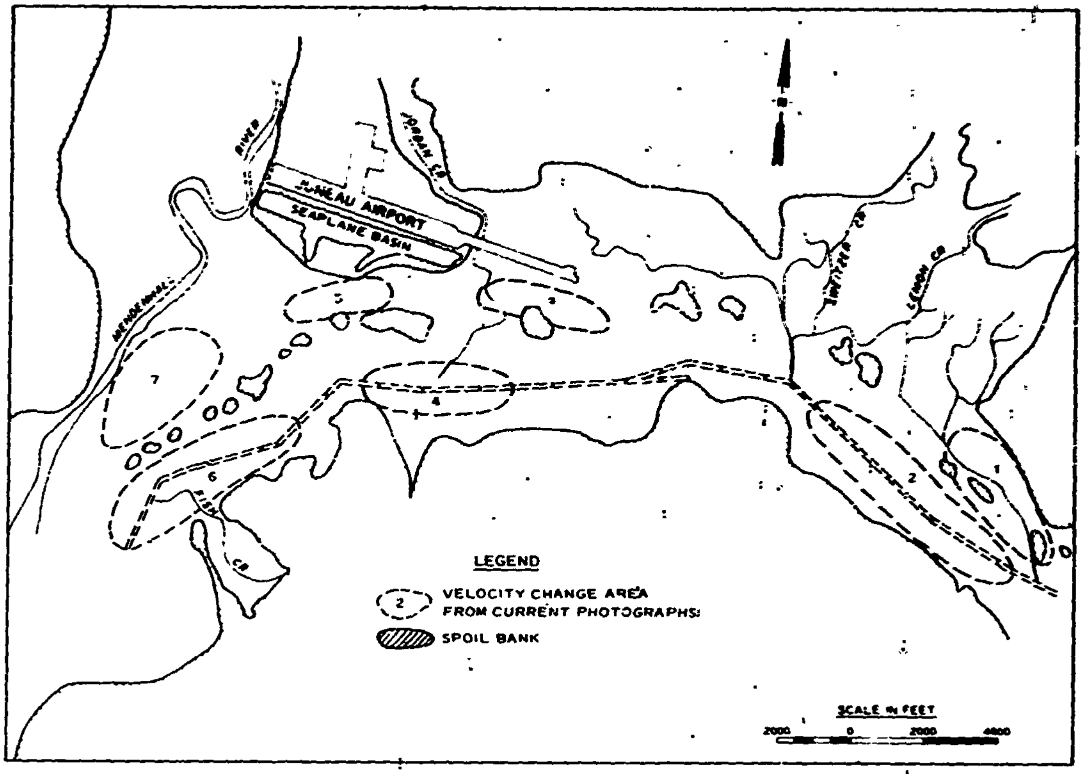

Fig. 15. Locations of areas subject to velocity changes as a result of dike plans

Plan 2

64. It was believed that the velocities for plan 1 conditions which occurred between the east end of the dike and the bankline were too high and would cause extensive scour in that area. Thus, the length of the dike was reduced for plan 2 by 2500 ft on the Juneau end. This considerably increased the cross-sectional area at the constriction between the end of the dike and the bankline. Plan 2 thus consisted of a 24,350-ft-long dike (fig. 12). The results of the shoaling test for this plan are presented in table 3 and plate 21 and indicate that the reduction in the dike length increased shoaling by only 1.9 percent as compared with plan 1, or a total reduction of 81.3 percent as compared with the base test. Although the difference in shoaling test results between plans 1 and 2 is too small to be considered significant, the increase occurred near the Juneau end of the channel as was to be expected.

65. Results of tidal elevation measurements are presented in plates 22-24. No significant changes occurred at the navigation channel gages (sta 7, 14, 18, and 21) as compared with plan 1. At the Lemon Creek gage, both the low- and high-water elevations for plan 2 were 0.2 to 0.5 ft lower than for plan 1. Because of the relatively minor change in model conditions for plan 2 as compared with plan 1, no velocity measurements were made for plan 2.

66. Because of the limited nature of the difference between plans 1 and 2, surface current photographs for plan 2 were made only for the immediate area around the Juneau end of the dike. Photos 38 and 39 were made at the times of hhw and llw, respectively. No appreciable differences were noted between these and the corresponding plan 1 photos 33 and 34. Maximum velocities observed in areas 1 and 2 are presented in table 4. Maximum ebb velocities in area 1 were 2.0 fps less than for plan 1, while maximum ebb and flood velocities in area 2 were about 0.5 fps greater than for plan 1. The length of bankline in area 1 which was subject to relatively high velocities was considerably less for plan 2 than for plan 1. Photos 40 and 41 are the most representative of strength of ebb and strength of flood conditions. Photo 42 shows the crosscurrent that developed near the end of the dike. This is essentially the same pattern that developed for plan 1 (photo 37).

Plan 3

67. During tests of plans 1 and 2, it appeared that the Fritz Cove (western) end of the dike was not serving any useful purpose. This portion of the dike was well aligned with the existing flow patterns and thus did not seem to have any effect on current velocities, current patterns, or sediment transport. The flow in that region is determined by a natural ridge along which about 12 spoil banks are located. Very little flow passes between these spoil banks for existing conditions (photos 8-32). It was therefore decided to remove 5000 ft from the Fritz Cove end of the plan 2 dike to determine if the dike could be shortened without increasing the shoaling rate. The plan 3 dike was thus 19,350 ft long (fig. 12). The shoaling test results are presented in table 3 and plate 29. Channel shoaling was reduced by 3.9 percent

as compared with plan 2, which cannot be considered a significant change, or a total reduction of 85.2 percent as compared with base conditions. The reduction in shoaling as compared with plan 2 actually occurred in the Juneau end of the channel, which does not seem reasonable since the reduction in dike length was at the other end of the dike.

68. Tidal elevation measurements are presented in plates 30-32. By comparing these with plates 22-24, it is seen that the high- and low-water elevations for plan 3 are generally about 0.2 to 0.5 ft lower than for plan 1 at the navigation channel gages. At the Lemon Creek gage, high-water elevations are 0.3 to 0.4 ft lower than those in plan 1 and low-water elevations are the same as in plan 1. Apparently the model tidal plane for this test was erroneously set about 0.3 ft too low. No velocity measurements were made for this plan.

69. Surface current photographs were made only at the Fritz Cove end of the navigation channel, since the dike modification involved in this plan was limited to that vicinity. Photos 43 and 44 were taken at the times of hhw and llw and show no significant differences as compared with the corresponding plan 1 photos 33 and 34. Maximum velocities observed in areas 6 and 7 are presented in table 4. Maximum ebb velocities in area 6 were increased by 1.0 fps as compared with plan 1, while maximum flood velocities were reduced by 1.0 fps. Maximum velocities in area 7 were the same for plans 1 and 3. Photos 43 and 45 are the most representative of strength of ebb and strength of flood conditions, respectively.

Plan 4

70. From visual observations made during plan 3, it was decided that the western 2100 ft of the dike was not effective in reducing channel shoaling. Thus for plan 4, the dike was shortened by 2100 ft on the Fritz Cove end, leaving a total dike length of 17,250 ft. In addition, it was observed that Fish Creek seemed to be contributing a significant amount of sediment to the Fritz Cove end of the navigation channel in sections 1-3. Therefore, it was decided to plug the mouth of Fish Creek where it enters the navigation channel and divert its flow directly to Fritz Cove. The elements of plan 4 are shown in fig. 12. Results of

the plan 4 shoaling test are presented in table 3 and plate 29. The reduction in dike length and diversion of Fish Creek of plan 4 caused a reduction in shoaling of 5.3 percent as compared with plan 3. While a difference in shoaling index of this magnitude should not be considered significant, it is important to note that in the area where the dike shortening and Fish Creek diversion were accomplished (shoaling sections 1-4), there was a reduction in shoaling of 4.6 percent. The total reduction in shoaling for this plan as compared with base conditions was 90.5 percent.

71. Because of the very minor differences between the elements of plans 3 and 4, no tidal elevation measurements were made for plan 4. Current velocities were measured, however, because no such measurements were made for plans 2 and 3. Current velocities for plan 4 at sta 1-4 are presented in plates 25-28. Compared with base conditions, the only significant increases in maximum velocities occurred at the surface and middepth of sta 2, which were increased by 2.0 and 1.0 fps. Maximum ebb velocities at sta 1 were reduced by 1.25 to 2.5 fps, and maximum surface and middepth flood velocities at sta 3 were reduced by 1.25 and 1.0 fps.

72. Surface current photographs were made for that portion of the model between the western end of the plan 4 dike and Fritz Cove. Photos 46 and 47 were made at the times of hhw and llw and show no significant differences as compared with either base test (photos 22 and 28) or plan 1 (photos 33 and 34) conditions. Table 4 shows the maximum current velocities observed in areas 5-7. Maximum ebb velocities in area 5 were 3.0 fps greater than those for the base test, and those in area 6 were 1.0 fps greater than for the base test. Maximum flood velocities in areas 5 and 6 and maximum ebb flood velocities in area 7 were not significantly different from those for the base test. Photos 48 and 49 are the most representative of strength of ebb and strength of flood conditions, respectively.

Discussion

73. Based primarily on the shoaling test results, it was decided that plan 4 was the best plan tested. This plan caused the greatest

reduction in shoaling (90.5 percent) and had the shortest length of dike. If the Fish Creek diversion had been included in the other plans, it is believed that shoaling for plans 1-3 would have been reduced by about 5.0 percent. Thus the results of all shoaling tests would have been essentially the same. The primary benefit of plan 4 as compared with plans 1-3 is therefore its lower construction cost.

74. Rather high velocities adjacent to the bankline can be observed in the photographs in areas 1, 3, and 5 and along the face of the dike near either end. These will require some sort of bank protection to ensure stability. It is believed that the crosscurrents which occur near the Juneau end of the dike are not strong enough to hamper navigation of the type vessels which normally use Gastineau Channel, nor do current velocities seem to have been increased sufficiently in any area to hamper navigation.

Channel Enlargement Tests

75. Plans 5-8 consisted of enlargement of the navigation channel, combined with either the elements of plan 4 or existing conditions. The enlarged channel dimensions investigated were 12 ft deep at mllw by 150 ft wide, and 30 ft deep at mllw by 300 ft wide. The existing project dimensions are 4 ft deep at mllw (including overdepth dredging) by 75 ft wide. Tests of an enlarged channel in combination with the best dike plan developed was a logical extension of the testing program, since material dredged from the channel could be used to construct the proposed dike. It seems reasonable to assume that when the proposed dike is constructed, the navigation channel will be redredged at least to the existing project dimensions. Since such a maintenance dredging operation would not furnish sufficient material with which to complete construction of the proposed dike, it would appear that the dike material could be economically provided by dredging a larger channel. The alignment of the navigation channel east of the existing project was not shown on any of the maps furnished by the Alaska District. The alignment used for this portion of the navigation channel was the best

that could be fitted in the thalweg of the existing channel.

12- by 150-ft navigation channel

76. Plan 5 consisted of a 12- by 150-ft navigation channel with no supplemental improvements (fig. 16). The results of the shoaling

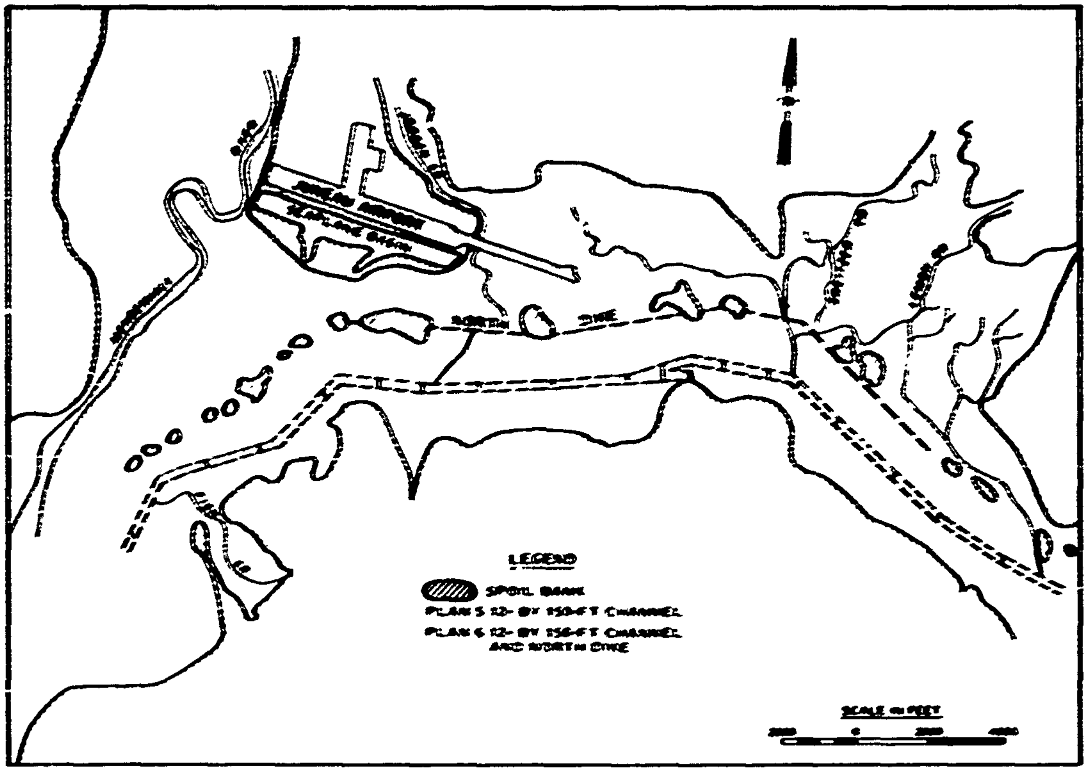

Fig. 16. Elements of plans 5 and 6

test for plan 5 are presented in table 5 and plate 33. Enlargement of the navigation channel without providing any other improvement works would increase channel shoaling by about 44.8 percent. Shoaling was actually reduced at both ends of the channel but was greatly increased in the Jordan Creek and the Sweitzer-Lemon Creek areas. For plans 5-8 an additional shoaling section (section 17) is shown. This section was added because deepening the channel would require lengthening the dredged channel on the Juneau end.

77. Measurements of tidal elevations are presented in plates 34-36. The enlarged channel caused only minor changes in tidal heights at sta 7 and Lemon Creek compared with base test conditions, but the

low-water elevations at sta 14, 18, and 21 were reduced by 0.7 to 3.2 ft. Thus, for plan 5 the low-water elevations were equal throughout the length of the channel. Velocity observations are presented in plates 37-40. Maximum ebb velocities at all depths at sta 1 and 4 (which are located near the ends of the channel) were generally reduced by 0.5 to 2.25 fps, while maximum flood velocities at these stations were generally reduced by 1.25 to 2.5 fps. These large reductions in maximum velocity were to be expected, because the flow area at the times of maximum current is limited primarily to the navigation channel: thus, the flow area was greatly increased with a corresponding decrease in velocity. Maximum surface and middepth ebb velocities at sta 3 (which is located in the central portion of the channel) were increased by 1.0 fps, while the maximum bottom ebb velocities were unchanged at this station. Maximum surface and middepth flood velocities at sta 3 were also increased by 1.0 fps. At sta 2, maximum surface and middepth east velocities were increased by 0.5 to 1.75. Maximum surface west velocities at sta 2 were increased by 1.25 fps. It is probable that the increase in velocities at these two stations (sta 2 and 3) was caused by increased efficiency of the channel. This view is supported by the fact that the time of maximum velocities with the enlarged channel was generally considerably earlier (as much as 3 hr) than for the existing channel.

78. Photos 50 and 51 show the surface current patterns at the times of hhw and llw and indicate no change in the waterline as compared with base test conditions (photos 22 and 28). Maximum surface velocities in the areas shown in fig. 15 (but outside the navigation channel) as determined from the photographs are presented in table 6. Maximum surface velocities in the areas at both ends of the navigation channel (areas 1, 2, and 6) were generally decreased; conversely, maximum surface velocities in the areas near the central portion of the channel (areas 3, 4, and 5) were generally increased. These are the same trends determined from the velocity measurements in the navigation channel (see plates 37-40). Photos 52 and 53 are the most representative of strength of ebb and strength of flood conditions, respectively. The only appreciable change in current patterns observed for plan 5 was the occurrence

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of a slight eddy on the flood phase of the tide just west of the mouth of Jordan Creek. This eddy is shown in photo 54, and the corresponding base test current pattern is shown in photo 21.

79. Plan 6 consisted of the 12- by 150-ft navigation channel in combination with the elements of plan 4, that is, the 17,250-ft-long dike and diversion of Fish Creek. This plan is also shown in fig. 16. The results of the plan 6 shoaling test are presented in table 7 and plate 41. The elements of plan 6 reduced shoaling by [illegible].4 percent, as compared with the enlarged channel of plan 5 without any other improvements. Shoaling was very light throughout the channel, except at the Juneau end. Heavy shoaling was observed in section 17; however, this section is quite long (3700 ft) so the material would be spread over a large area. On the basis of shoaling rate per unit area, the 3045 cc recovered in section 17 corresponds to about 5.5 cc per 1000 sq ft (prototype) of bottom surface area in the navigation channel. Referring to the results of the shoaling verification, it was found that the shoaling rates per unit area in sections 5 and 13 were 5.9 and 5.7 cc per 1000 sq ft (prototype), respectively. Based on the end-area cross sections described in paragraph 39, the average depth of fill in sections 5 and 13 during the 2-yr period 1961-63 was 3 to 4 ft. Since it is obvious that the shoaling in section 17 would not be uniform, it is assumed that the maximum depth of fill would be on the order of 6 ft over a period of 2 yr. Since previous tests had shown that an easterly extension of the dike would create excessive velocities between the dike and the bankline, no such plan was investigated to reduce shoaling in section 17. It is believed that improvement of the Lemon Creek channel to deep water beyond the eastern end of the navigation channel would result in reduced shoaling in section 17, but no test was conducted of such a plan.

80. Observations of tidal elevations are presented in plates 34-36. No significant changes were observed at the gages located along the navigation channel as compared with plan 5, and the changes at the Lemon Creek gage were typical of the changes observed for all previous dike plans. Results of the velocity measurements are shown in plates 37-40.

Compared with plan 5, the significant changes in maximum velocities observed in plan 6 were as follows: at sta 1, the maximum surface flood velocity was reduced by 0.5 fps, while the maximum middepth flood velocity was increased by 0.5 fps; at sta 2, the maximum surface east velocity was reduced by 0.5 fps, maximum middepth and bottom east velocities were increased by 1.25 fps, and maximum surface and bottom west velocities were reduced by 1.5 and 0.5 fps, respectively; at sta 3, maximum ebb velocities were reduced by 0.5 fps, while maximum flood velocities were increased by 0.5 to 2.0 fps; and at sta 4, maximum ebb velocities were reduced by 0.5 to 1.25 fps, while maximum flood velocities were increased by 0.5 to 1.0 fps.

81. Photos 55-60 show surface current patterns for plan 6. Photo 55 shows conditions at the time of hhw. Comparison of photos 55 and 50 indicates that there is no difference in the waterlines for conditions of plans 5 and 6; on the other hand, photo 56, which was taken at the time of llw, indicates extensive areas behind the plan 6 dike will remain flooded rather than becoming completely exposed as in plan 5 (photo 51). Maximum surface velocities in the areas shown in fig. 15 (but outside the limits of the navigation channel) are presented in table 6. Compared with plan 5, the maximum ebb velocity observed between the Juneau end of the dike and the bankline (area 1) was increased from 3.0 to 5.5 fps, the maximum ebb velocity observed between the dike and the seaplane basin (area 5) was increased from 1.5 to 3.5 fps, while the maximum ebb velocity observed near the mouth of Jordan Creek (area 4) was reduced from 4.5 to 1.5 fps. Photos 57 and 58 are the most representative of surface current patterns at the times of strength of ebb and strength of flood, respectively. Crosscurrents near the mouth of Jordan Creek and the Juneau end of the dike developed during the flood phase of tide and are shown in photo 59. Similar crosscurrents were observed during tests of plan 1 (photo 37). Also during the flood phase of the tide, a rather strong eddy developed around the navigation channel near the Juneau end of the dike in area 2 (photo 60).

<u>30- by 300-ft channel</u>

82. Plan 7 consisted of a 30- by 300-ft navigation channel with

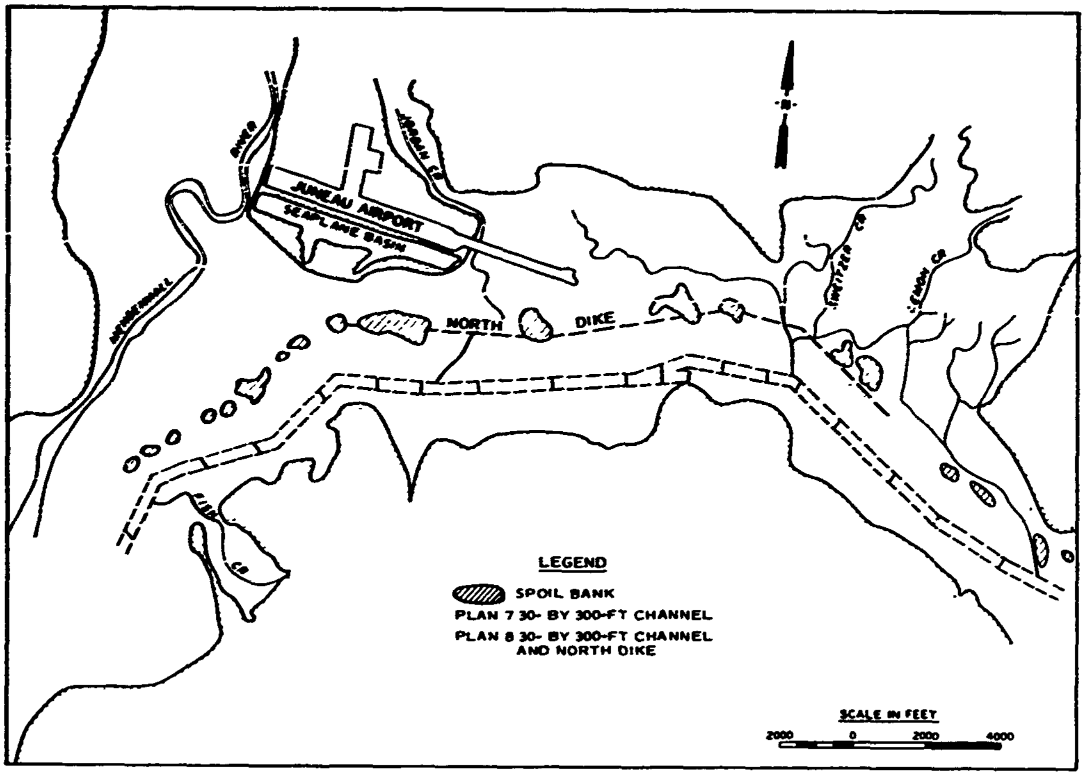

Fig. 17. Elements of plans 7 and 8

no other improvements (fig. 17). The results of the plan 7 shoaling test, presented in table 5 and plate 33, show that this channel enlargement would increase shoaling by about 109.1 percent. The primary peak of the shoaling distribution pattern was shifted to the west from shoaling sections 13 and 14 (just east of the mouth of Sweitzer Creek) to section 11 (just west of the mouth of Sweitzer Creek).

83. Tidal elevation measurements for plan 7 are presented in plates 42-44. The changes observed were essentially the same as those observed in plan 5. Velocity observations are presented in plates 45-48. Gross reductions of maximum velocities were observed at all four stations. Only the maximum west velocities at sta 2 and the maximum ebb velocities at sta 3 were relatively unchanged. The reductions of maximum velocities varied from 1.5 to 3.25 fps. Reduced velocities were to be expected because of the large increase in flow area effected by the enlarged channel.

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84. Photos 61-64 show the surface current patterns for plan 7. Conditions at the times of hhw and llw are shown in photos 61 and 62. Comparison of these photographs with photos 22 and 28 indicates that the enlarged channel had no effect on the waterline at hhw and llw. Maximum surface current velocities as determined from the photographs for the areas shown in fig. 15 are presented in table 6. Maximum surface velocities in these areas were generally reduced by 1.0 to 3.0 fps, except that the maximum ebb velocity in area 3 was increased by 1.0 fps. Photos 63 and 64 are the most representative of conditions at the strength of ebb and strength of flood, respectively.

85. Plan 8 (fig. 17) consisted of the 30- by 300-ft channel in combination with the 17,250-ft-long dike and diversion of Fish Creek as developed in plan 4. The results of the plan 8 shoaling test are presented in table 8 and plate 49. Shoaling was reduced by 67.5 percent as compared with plan 7 but heavy shoaling occurred at the Juneau end of the navigation channel in shoaling sections 16 and 17. The shoaling rates per unit area in sections 16 and 17 were 1.8 and 3.9 cc per 1000 sq ft (prototype), respectively. The corresponding approximate maximum depths of fill in these sections during a 2-yr period for plan 8 conditions are 2 and 4 ft.

86. Results of the tidal elevation measurements for plan 8 are presented in plates 42-44. No significant changes as compared with plan 7 were observed at the channel gages, and the increase in low-water elevation observed at the Lemon Creek gage was typical of all other dike plans. Velocity observations are presented in plates 45-48. Compared with plan 7, the only significant changes in maximum velocities were as follows: maximum surface ebb velocity at sta 1 was reduced by 0.75 fps, maximum surface flood velocity at sta 4 was reduced by 1.25 fps, and maximum surface ebb velocity at sta 3 was increased by 1.0 fps.

87. Surface current pattern photos 65 and 66 were taken at the times of hhw and llw for plan 8, respectively. No change was observed in the high waterline, and the low waterline was typical of other dike tests. Maximum surface current velocities as determined from the photographs for the area shown in fig. 15 are presented in table 6. Compared

with plan 7, significant velocity changes were observed in areas 1, 3, 4, and 5. In area 1, maximum surface ebb and flood velocities were increased by 3.0 and 1.0 fps, respectively. In area 5, maximum surface ebb and flood velocities were increased by 1.5 and 2.0 fps, respectively. In area 3, the maximum surface flood velocity was increased by 1.0 fps. In area 4, the maximum surface flood velocity was reduced by 1.5 fps. Photos 67 and 68 are the most representative of strength of ebb and strength of flood, respectively.

Discussion

88. Shoaling test results show that for either of the enlarged channels combined with the proposed dike, rather heavy shoaling will occur at the Juneau end of the channel in sections 16 and 17. It is believed that this situation can be alleviated by improving the Lemon Creek channel to carry ebb flows directly into the deepwater portion of Gastineau Channel (fig. 18), although this configuration was unfortunately not subjected to testing in the model. The same effect could be

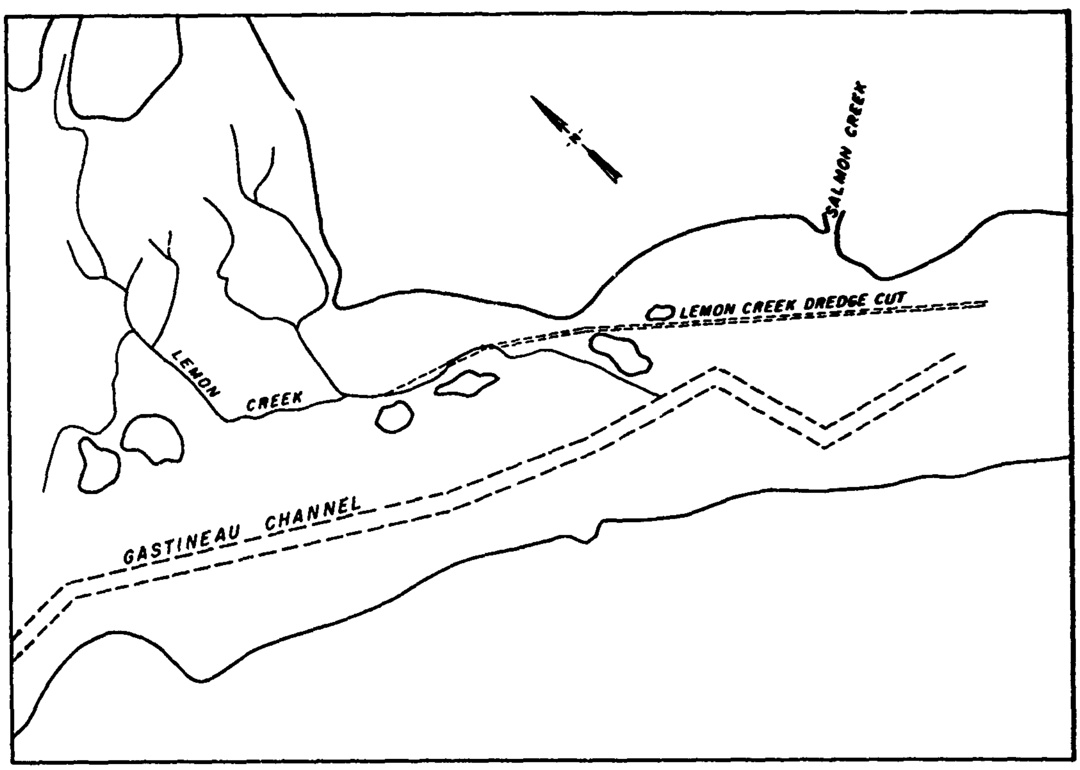

Fig. 18. Proposed diversion of Lemon Creek

obtained by extending the dike about 8000 ft toward Juneau; however, this would result in excessive velocities between the dike and the bankline over that entire distance and would probably cause a considerable reduction of high-water elevations behind the dike.

89. Relatively high velocities adjacent to the dike and the bankline were observed in areas 1, 3, and 5 for the plans involving channel enlargement and the dike. These will necessitate some sort of protection of the bankline and the face of the dike near each end.

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PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

90. Based on analysis of available prototype information and the results of model tests reported herein, the following conclusions are drawn:

- a. The Mendenhall River does not contribute significantly to shoaling of the navigation channel.
- b. The heavy shoaling in the navigation channel observed in the first year after construction was caused primarily by sloughing of the side slopes. In addition, the breach in the Juneau Airport seaplane basin caused heavy shoaling at the mouth of Jordan Creek.
- c. For any of the dike plans tested in combination with the existing channel, shoaling in the navigation channel will be reduced by about 80 to 85 percent. Diversion of Fish Creek will reduce channel shoaling by about an additional 5 percent.
- d. Enlargement of the navigation channel to dimensions of 12 by 150 ft will increase shoaling in the navigation channel by about 45 percent; enlargement of the channel to 30 by 300 ft will increase shoaling by about 110 percent.
- e. The 17,250-ft-long dike and diversion of Fish Creek, in combination with the 12- by 150-ft channel, will reduce shoaling by about 60 percent as compared with base conditions, while these same improvements with the 30- by 300-ft channel will reduce shoaling by about 30 percent.
- f. Either of the enlarged channels in combination with the improvements will cause rather heavy shoaling in the Juneau end of the channel (sections 16 and 17).
- g. For all of the plans tested, current velocities and current patterns should be satisfactory from the standpoint of navigation.
- h. For all plans involving a dike, relatively high velocities will occur near the ends of the dike, along the bankline opposite the ends of the dike, and along the bankline at the Juneau end of the airport runway.
- i. Because of the head differential measured across all of the proposed dikes tested, a substantial flow would develop across the top of the dike if it were constructed

with a top elevation below hhw. This flow could cause severe damage to the structure unless extensive protection were provided.

j. With any of the dike plans, a substantial area behind the dike will remain flooded at the time of low water.

Recommendations

91. Based on the results of the model tests and the subsequent analysis thereof, the following recommendations are made:

a. The 17,250-ft-long dike and Fish Creek diversion (plan 4) should be constructed if economically justified. The top elevation of the dike should be above hhw, and the dike should be impermeable.

b. The ends of the proposed dike and the bankline in the vicinities of the seaplane basin, the east end of the airport runway, and Vanderbilt Hill should be protected against erosion by relatively high current velocities.

c. It is suggested that the Lemon Creek channel be improved from the upstream end of the proposed dike to its downstreammost junction with the navigation channel. This would reduce the lateral flow between Lemon Creek and the navigation channel and thus reduce the possibility of shoaling in that reach of the channel.

d. If the navigation channel is enlarged, it is recommended the Lemon Creek channel not only be improved but also be diverted from the navigation channel directly into deep water near Salmon Creek.

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Table 1

Shoaling Test Injection Schedule

Cycle	Time	Location and Amount of Injection, cc			
		Sweitzer Creek	Jordan Creek	Fish Creek	Gage 18
Prior to test		6,000	0	0	0
0	0200-0500	2,000	1,000	0	0
0	1400-1800	2,000	1,000	0	0
1	0200-0500	2,000	1,000	0	0
1	1400-1800	2,000	1,000	0	0
2	0200-0500	2,000	1,000	0	0
2	1400-1800	2,000	1,000	0	0
3	0200-0500	2,000	1,000	0	0
3	1400-1800	2,000	1,000	0	0
4	0200-0500	2,000	1,000	1000	1000
4	1400-1800	2,000	1,000	1000	1000
5	0200-0500	2,000	0	1000	0
5	1400-1800	2,000	0	1000	0
6	0200-0500	2,000	0	1000	0
6	1400-1800	2,000	0	1000	0
7	0200-0500	2,000	0	1000	0
	Total	36,000	10,000	7000	2000

Table 2

Results of Shoaling Tests

Shoaling Verification and Base Test

Shoaling Section	Shoaling Verification: Material Recovered cc	Shoaling Verification: % of Total Material Recovered	Base Test: Material Recovered cc	Base Test: % of Verification Total Material Recovered
1	490	5.7	225	2.6
2	175	2.0	415	4.9
3	317	3.7	485	5.7
4	705	8.3	400	4.7
5	530	6.2	700	8.2
6	340	4.0	1,380	16.2
7	1185	13.9	665	7.8
8	460	5.4	25	0.3
9	50	0.6	93	1.1
10	25	0.3	550	6.4
11	225	2.6	1,110	13.0
12	290	3.4	870	10.2
13	685	8.0	1,860	21.8
14	1505	17.7	1,745	20.5
15	845	9.0	737	8.6
16	705	8.3	980	11.5
Total	8532	100.0	12,240	
Shoaling Index				143.5*

* Shoaling index is the total amount of material recovered for the base test divided by the total amount of material recovered for the shoaling verification.

Table 3

Results of Shoaling Tests, Plans 1-4

Shoaling Section	Base Test: Material Recovered cc	Base Test: % of Total Material Recovered	Plan 1: Material Recovered cc	Plan 1: % of Base Test Total Material Recovered	Plan 2: Material Recovered cc	Plan 2: % of Base Test Total Material Recovered	Plan 3: Material Recovered cc	Plan 3: % of Base Test Total Material Recovered	Plan 4: Material Recovered cc	Plan 4: % of Base Test Total Material Recovered
1	225	1.8	75	0.6	125	1.0	115	0.9	5	0.0
2	415	3.4	555	4.5	515	4.2	365	3.0	15	0.1
3	485	4.0	450	3.6	415	3.4	195	1.6	80	0.7
4	400	3.3	80	0.7	125	1.0	62	0.5	70	0.6
5	700	5.7	140	1.1	102	0.8	82	0.7	30	0.2
6	1,380	11.3	245	2.0	22	0.2	280	2.3	210	1.7
7	665	5.4	25	0.2	0	0	85	0.7	140	1.1
8	25	0.2	10	0.1	0	0	15	0.1	70	0.6
9	93	0.8	38	0.3	0	0	10	0.1	92	0.8
10	550	4.5	13	0.1	0	0	10	0.1	20	0.2
11	1,110	9.1	5	0.0	18	0.2	12	0.1	10	0.1
12	870	7.1	20	0.2	98	0.8	42	0.3	15	0.1
13	1,860	15.2	133	1.1	300	2.5	70	0.6	70	0.6
14	1,745	14.2	45	0.4	165	1.3	15	0.1	35	0.3
15	737	6.0	45	0.4	52	0.4	55	0.4	75	0.6
16	980	8.0	165	1.3	350	2.9	400	3.3	225	1.8
Total	12,240	100.0	2054		2287		1816		1162	
Shoaling Index				16.8*		18.7*		14.8*		9.5*

* Shoaling index is the total amount of material recovered for a plan test divided by the total amount of material recovered for the base test.

Table 4

Maximum Surface Current Velocities

Dike Plans

Area	Current Direction	Maximum Surface Velocity, fps Base Test	Plan 1	Plan 2	Plan 3	Plan 4
1	Ebb	3.5	6.0	4.0	--	--
	Flood	4.0	4.5	4.5	--	--
2	Ebb	4.5	2.5	3.0	--	--
	Flood	3.0	2.0	2.5	--	--
3	Ebb	1.5	0.5	--	--	--
	Flood	2.0	4.0	--	--	--
4	Ebb	3.5	1.0	--	--	--
	Flood	4.0	2.5	--	--	--
5	Ebb	1.5	2.5	--	--	4.5
	Flood	2.0	3.5	--	--	2.5
6	Ebb	4.5	2.5	--	3.5	5.5
	Flood	4.5	4.0	--	3.0	4.5
7	Ebb	3.0	3.0	--	3.0	3.0
	Flood	2.0	2.0	--	2.0	2.5

Note: These velocities were measured on photographs of surface current patterns and were measured outside the limits of the navigation channel. Areas 1-7 are shown in fig. 15.

Table 5

Results of Shoaling Tests, Plans 5 and 7

Shoaling Section	Base Test: Material Recovered cc	Base Test: % of Total Material Recovered	Plan 5: Material Recovered cc	Plan 5: % of Base Test Total Material Recovered	Plan 7: Material Recovered cc	Plan 7: % of Base Test Total Material Recovered
1	225	1.8	37	0.3	1,270	10.4
2	415	3.4	35	0.3	50	0.4
3	485	4.0	40	0.3	220	1.8
4	400	3.3	30	0.2	255	2.1
5	700	5.7	980	8.0	75	0.6
6	1,380	11.3	2,230	18.2	3,725	30.4
7	665	5.4	282	2.3	88	0.7
8	25	0.2	50	0.4	147	1.2
9	93	0.8	33	0.3	300	2.4
10	550	4.5	670	5.5	1,627	13.3
11	1,110	9.1	2,320	18.9	10,915	89.2
12	870	7.1	2,420	19.8	6,350	51.9
13	1,860	15.2	5,615	45.9	550	4.5
14	1,745	14.2	2,875	23.5	25	0.2
15	737	6.0	23	0.2	0	0
16	980	8.0	10	0.1	0	0
17	0	0	80	0.6	0	0
Total	12,240	100.0	17,732		25,597	
Shoaling Index				144.8*		209.1*

* Shoaling index is the total amount of material recovered for a plan test divided by the total amount of material recovered for the base test.

Table 6

Maximum Surface Current Velocities

Channel Enlargement Plans

Area	Current Direction	Maximum Surface Velocity, fps				
		Base Test	Plan 5	Plan 6	Plan 7	Plan 8
1	Ebb	3.5	3.0	5.5	1.0	4.0
	Flood	4.0	3.0	3.5	3.0	4.0
2	Ebb	4.5	2.0	2.0	1.5	1.5
	Flood	3.0	1.5	1.5	2.0	1.5
3	Ebb	1.5	2.0	2.5	2.5	2.0
	Flood	2.0	2.0	1.5	2.0	3.0
4	Ebb	3.5	4.5	1.5	1.5	1.5
	Flood	4.0	4.5	3.5	3.0	1.5
5	Ebb	1.5	1.5	3.5	2.0	3.5
	Flood	2.0	3.0	3.5	1.0	3.0
6	Ebb	4.5	3.0	3.5	2.0	1.5
	Flood	4.5	4.0	4.5	2.0	2.0
7	Ebb	3.0	3.0	3.0	3.0	3.0
	Flood	2.0	2.5	2.5	2.0	1.5

Note: These velocities were measured on photographs of surface current patterns and were measured outside the limits of the navigation channel. Areas 1-7 are shown in fig. 15.

Table 7

Results of Shoaling Tests

Plan 6

Shoaling Section	Plan 5 Material Recovered cc	Plan 5 % of Total Material Recovered	Plan 6 Material Recovered cc	Plan 6 % of Plan 5 Total Material Recovered
1	37	0.2	0	0
2	35	0.2	20	0.1
3	40	0.2	220	1.2
4	30	0.2	55	0.3
5	980	5.5	200	1.1
6	2,230	12.6	125	0.7
7	282	1.6	25	0.1
8	50	0.3	0	0
9	33	0.2	0	0
10	670	3.8	0	0
11	2,320	13.1	0	0
12	2,420	13.6	97	0.6
13	5,615	31.7	275	1.6
14	2,875	16.2	0	0
15	23	0.1	10	0.1
16	10	0.1	465	2.6
17	80	0.4	3045	17.6
Total	17,732	100.0	4537	
Shoaling Index				25.6*

* Shoaling index is the total amount of material recovered for plan 6 divided by the total amount of material recovered for plan 5.

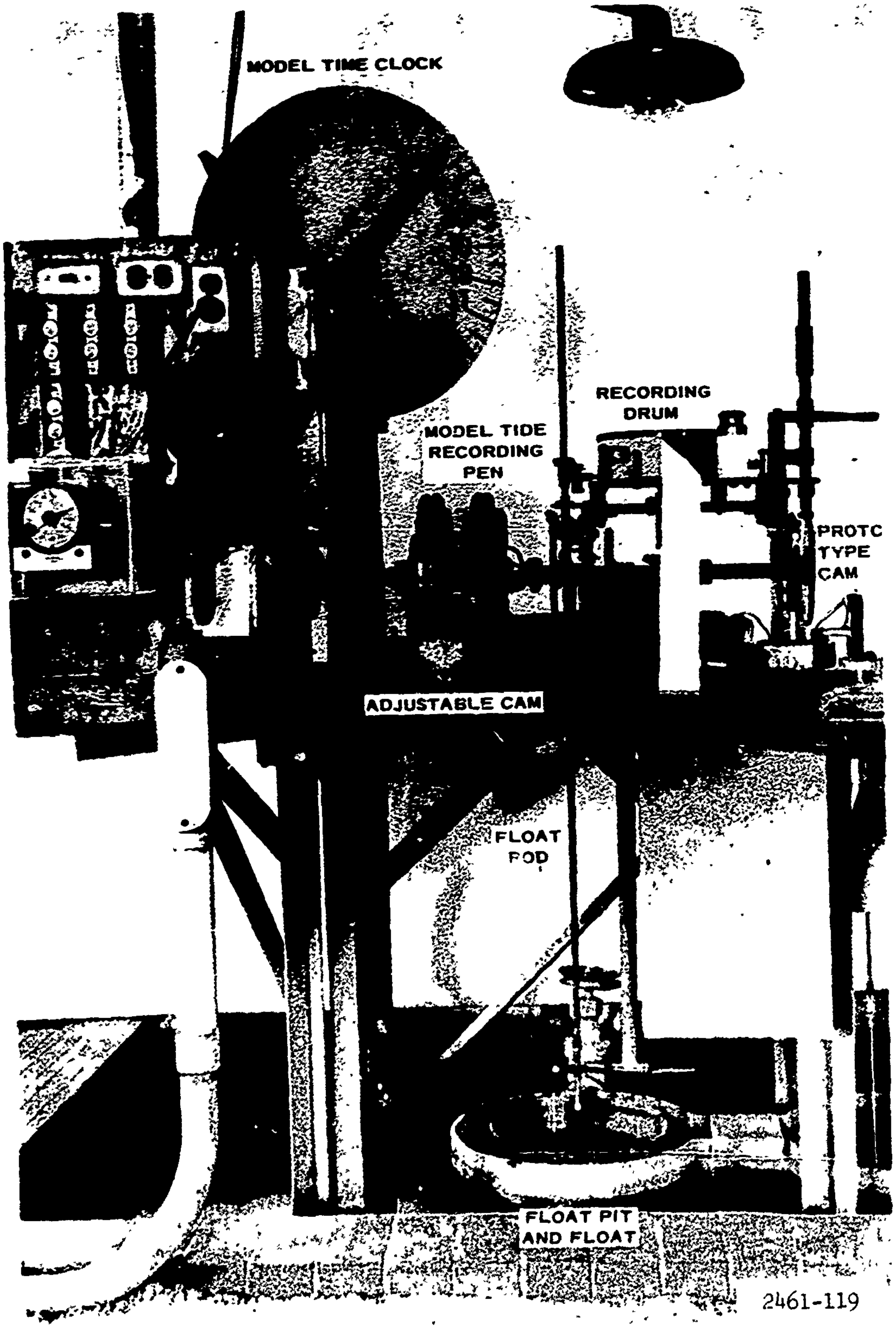
Table 8

Results of Shoaling Tests

Plan 8

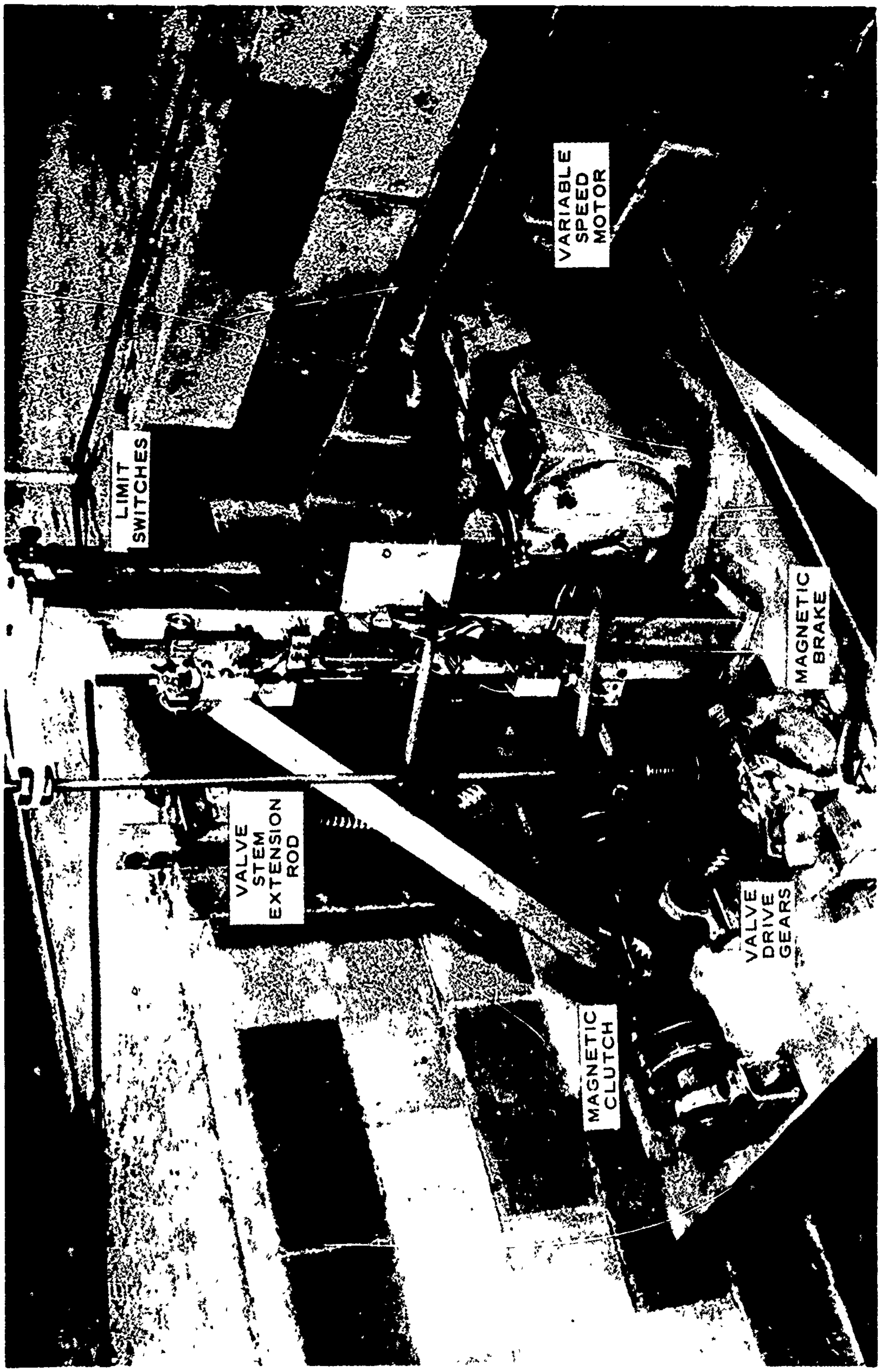
Shoaling Section	Plan 7 Material Recovered cc	Plan 7 % of Total Material Recovered	Plan 8 Material Recovered cc	Plan 8 % of Plan 7 Total Material Recovered
1	1,270	5.0	970	3.8
2	50	0.2	790	3.1
3	220	0.9	300	1.2
4	255	1.0	170	0.7
5	75	0.3	25	0.1
6	3,725	14.5	50	0.2
7	88	0.3	25	0.1
8	147	0.6	0	0
9	300	1.2	25	0.1
10	1,627	6.4	0	0
11	10,915	42.6	50	0.2
12	6,350	24.8	160	0.6
13	550	2.1	130	0.5
14	25	0.1	90	0.4
15	0	0	102	0.4
16	0	0	1085	4.2
17	0	0	4335	16.9
Total	25,597	100.0	8307	
Shoaling Index				32.5*

* Shoaling index is total amount of material recovered for plan 8 divided by total amount of material recovered for plan 7.



TIDE CONTROL TABLE

PHOTO 1

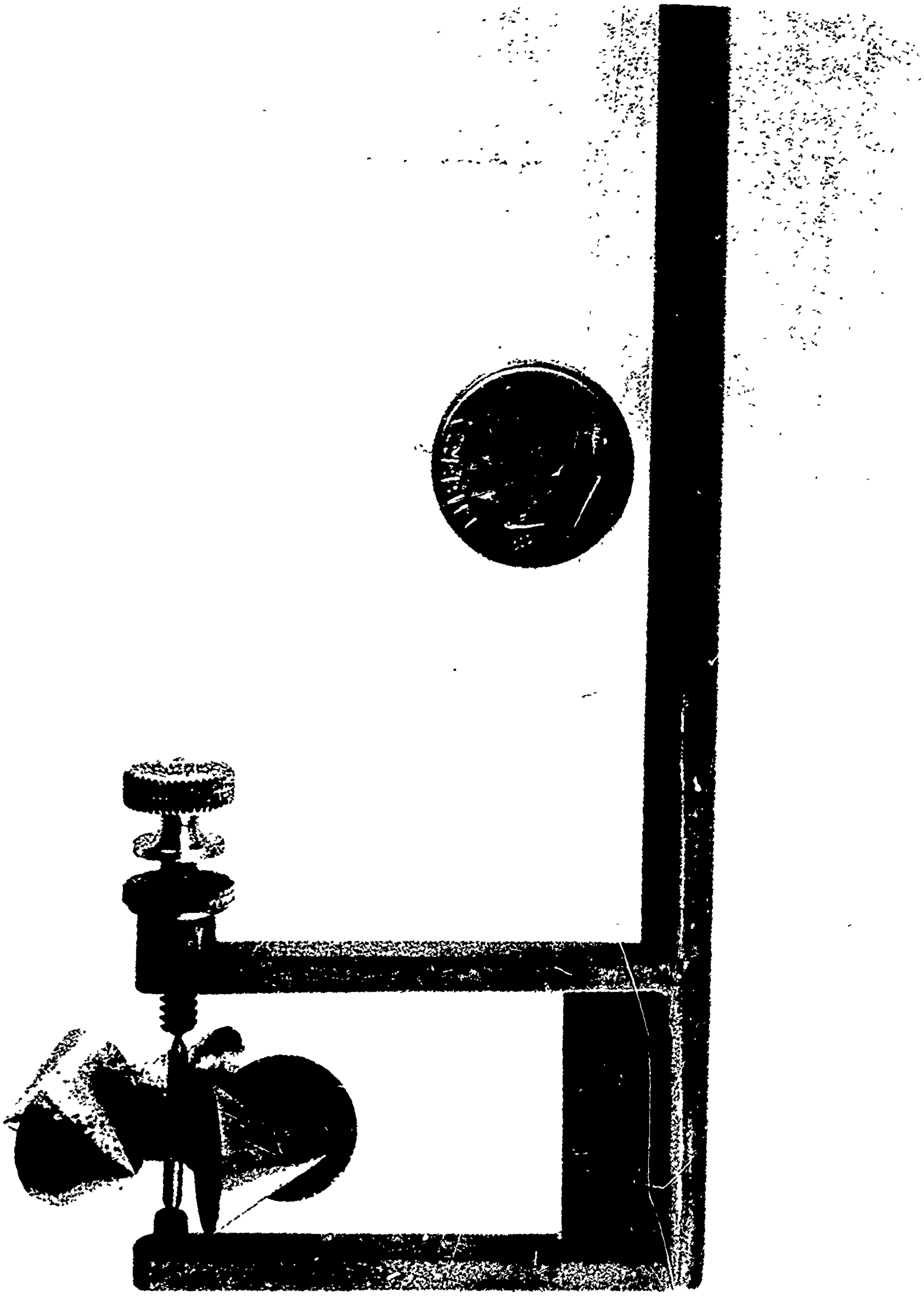


AUTOMATIC OUTFLOW VALVE

PHOTO 2

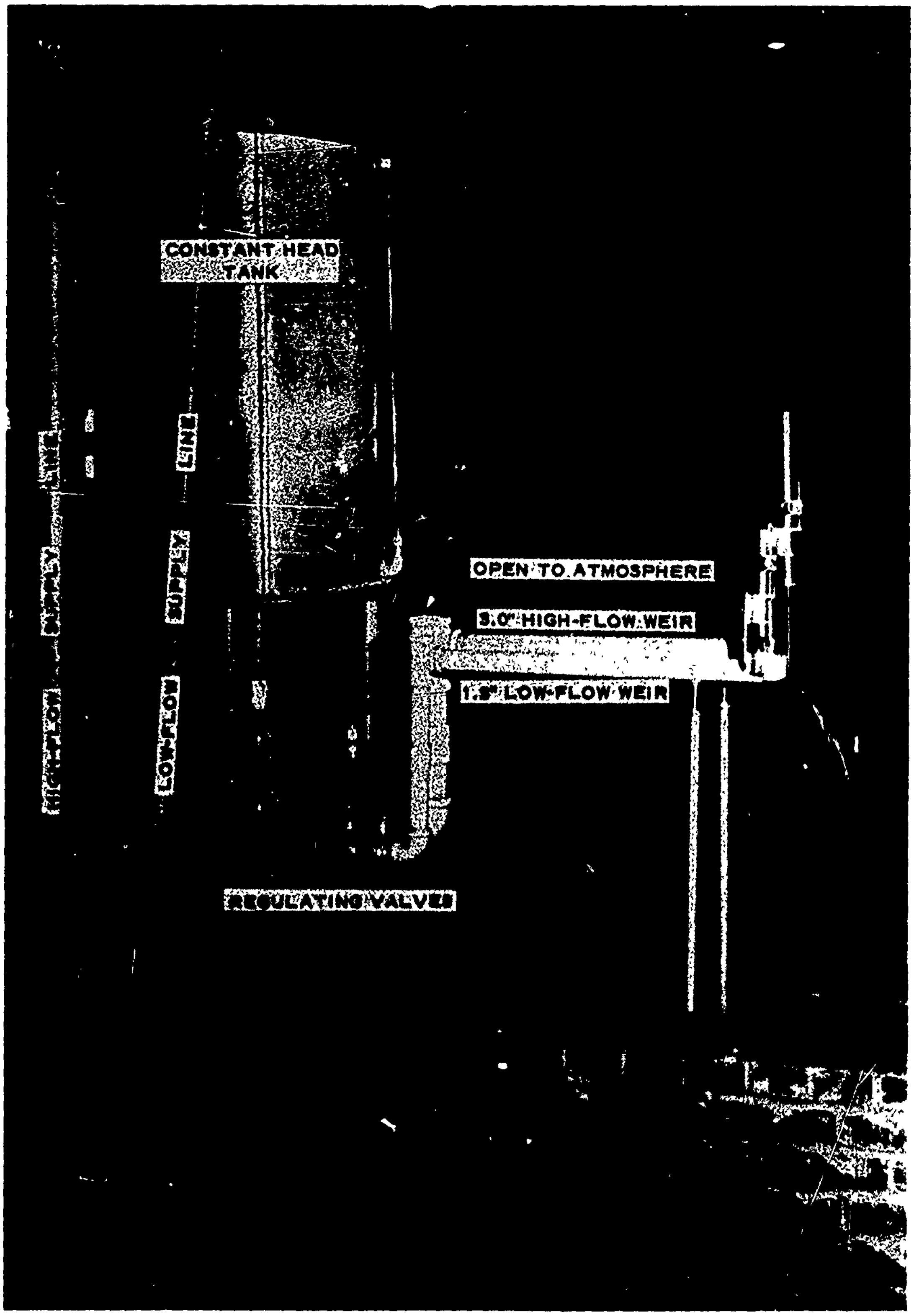
POINT GAGE

PHOTO 3



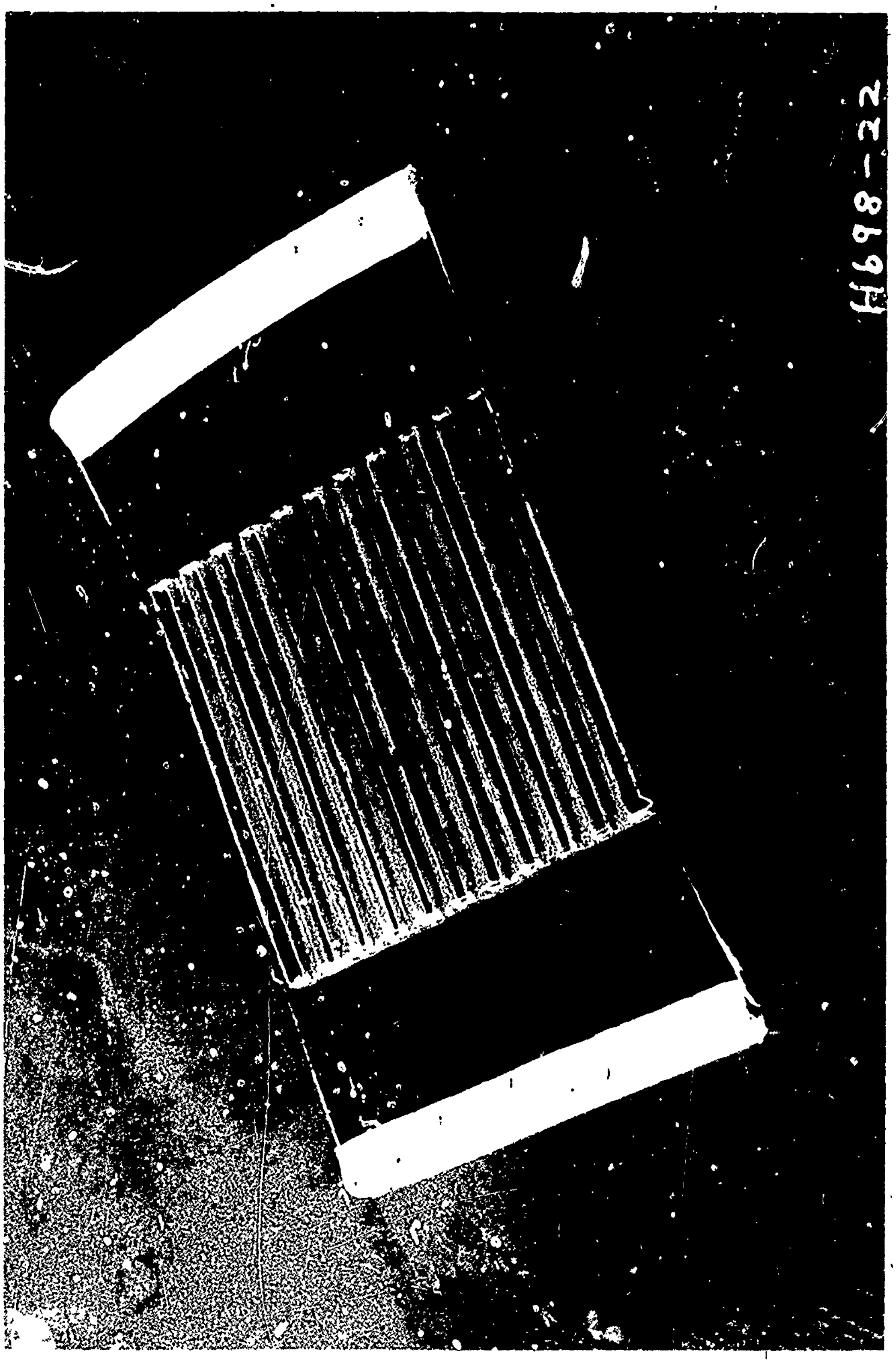
VELOCITY METER

PHOTO 4



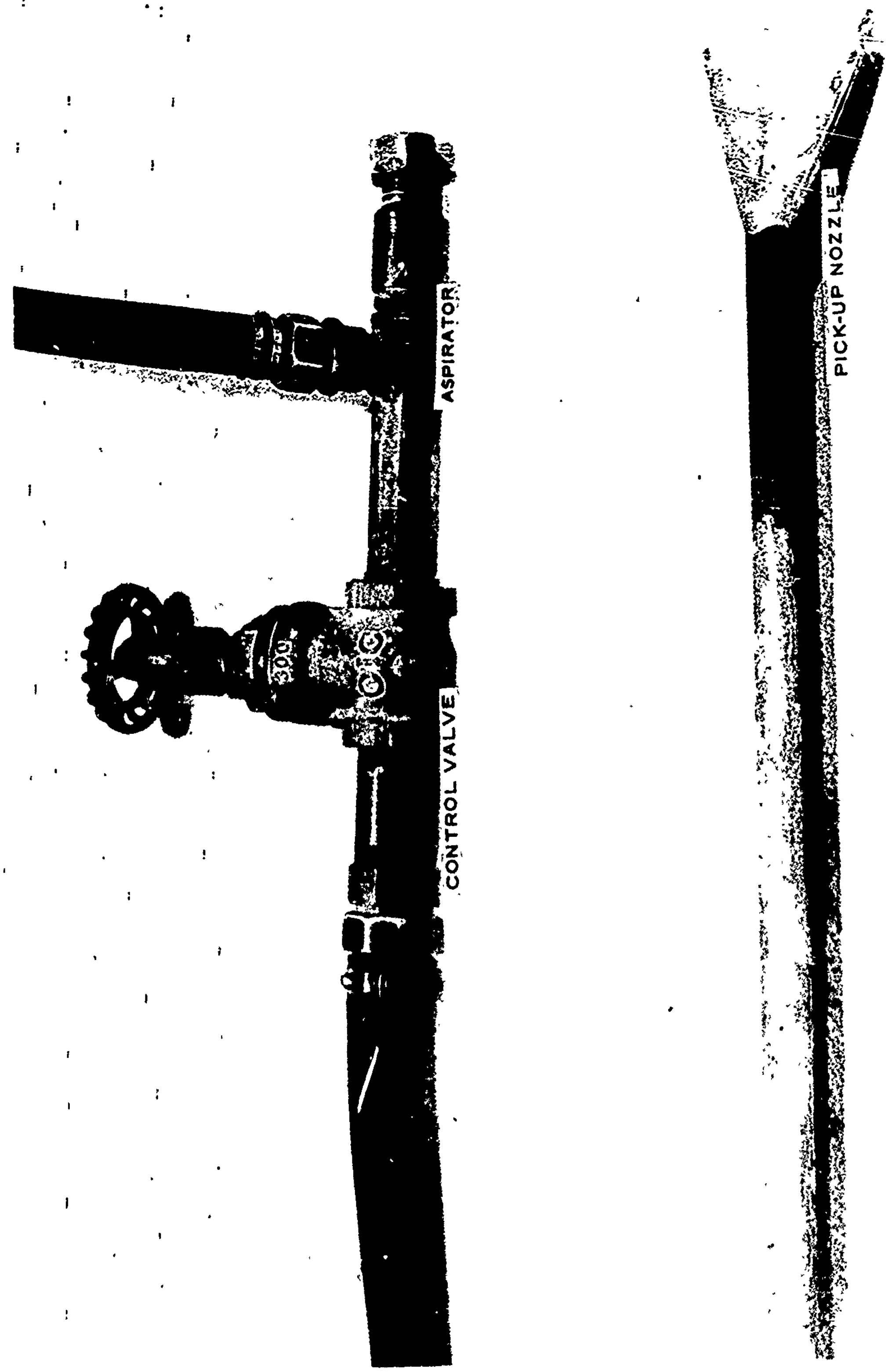
VAN LEER WEIR

PHOTO 5



FLOATING SKIMMING WEIR

PHOTO 6



SHOALING APPARATUS

PHOTO 7

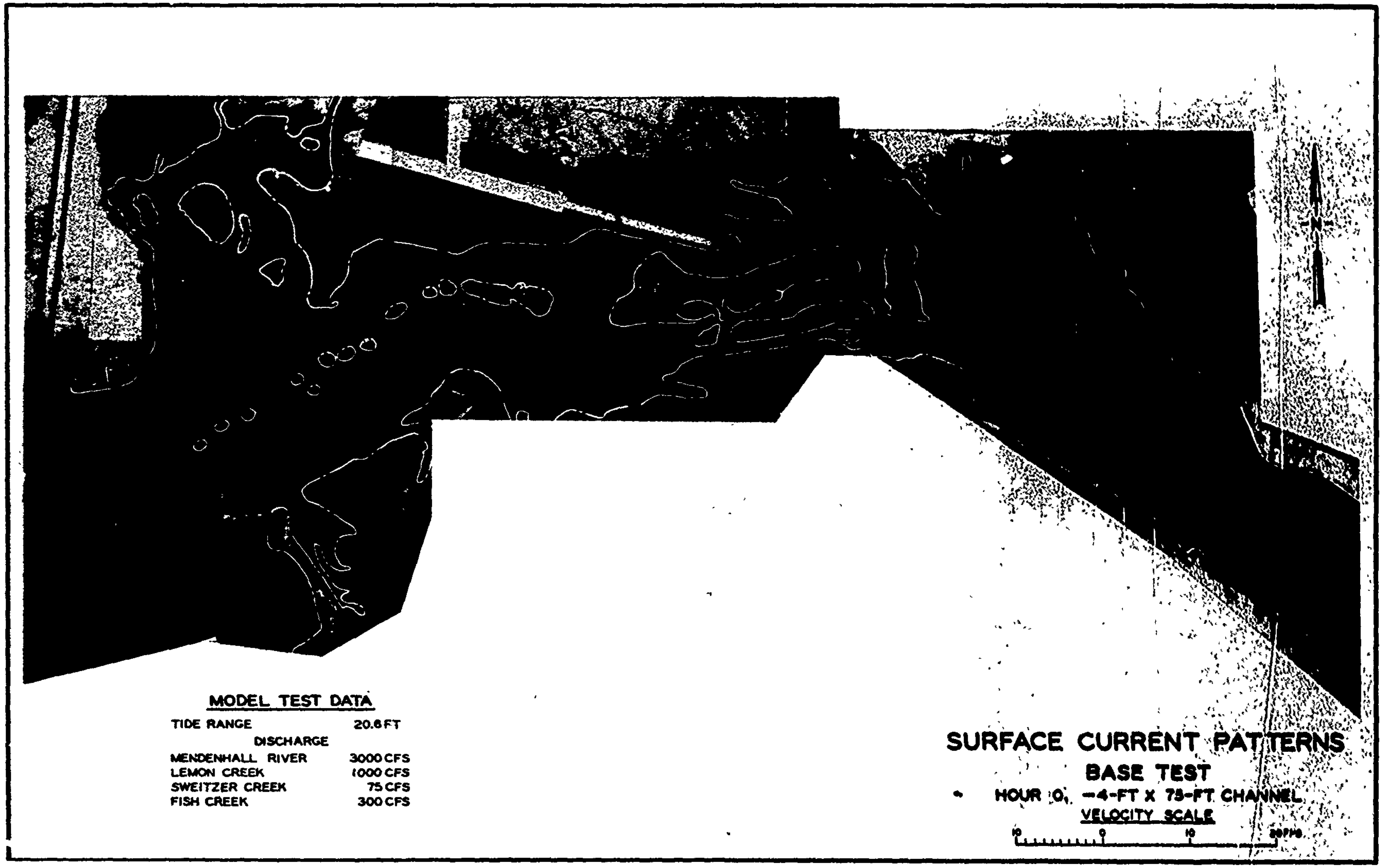

MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 0, −4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 8

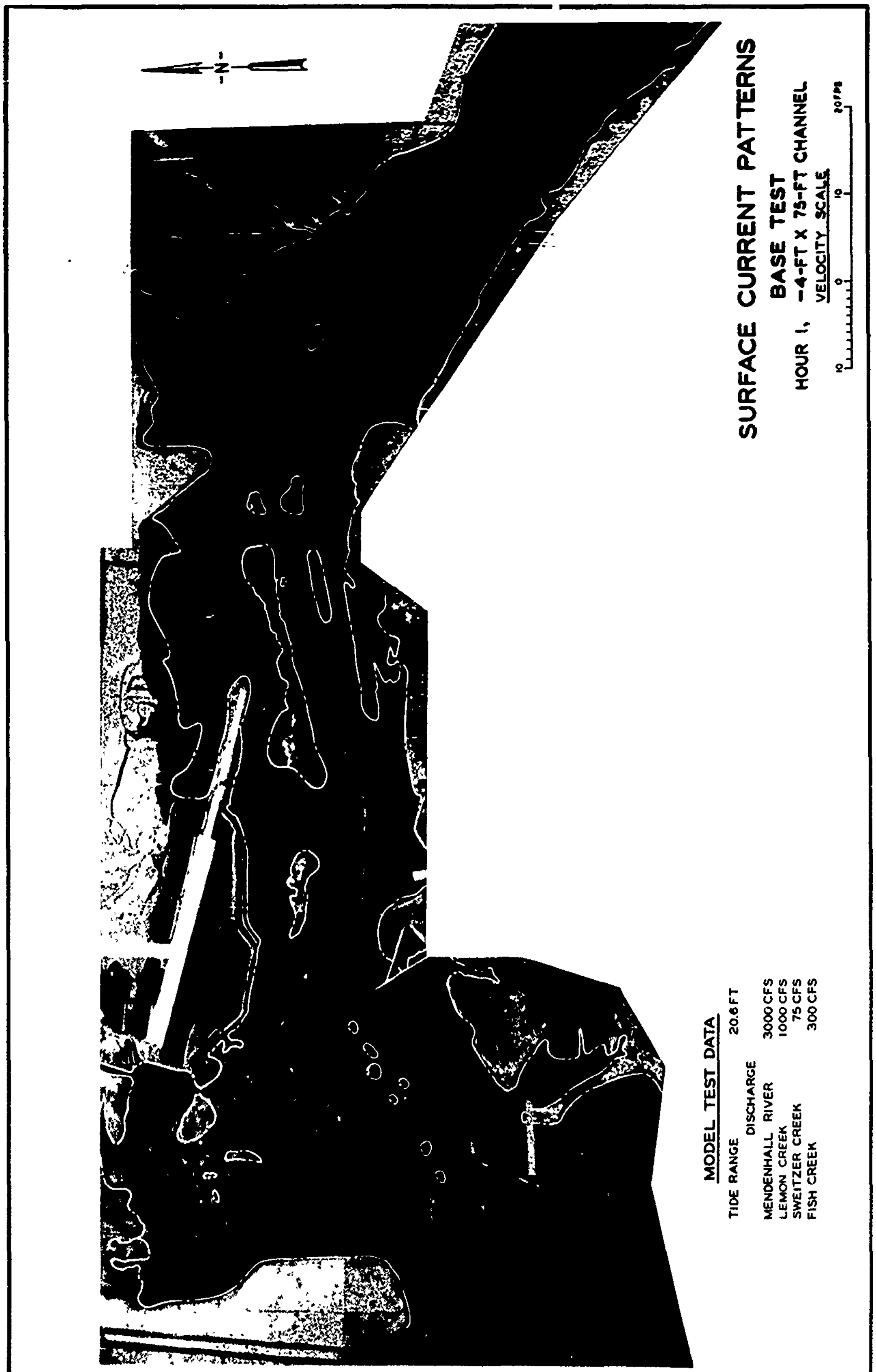
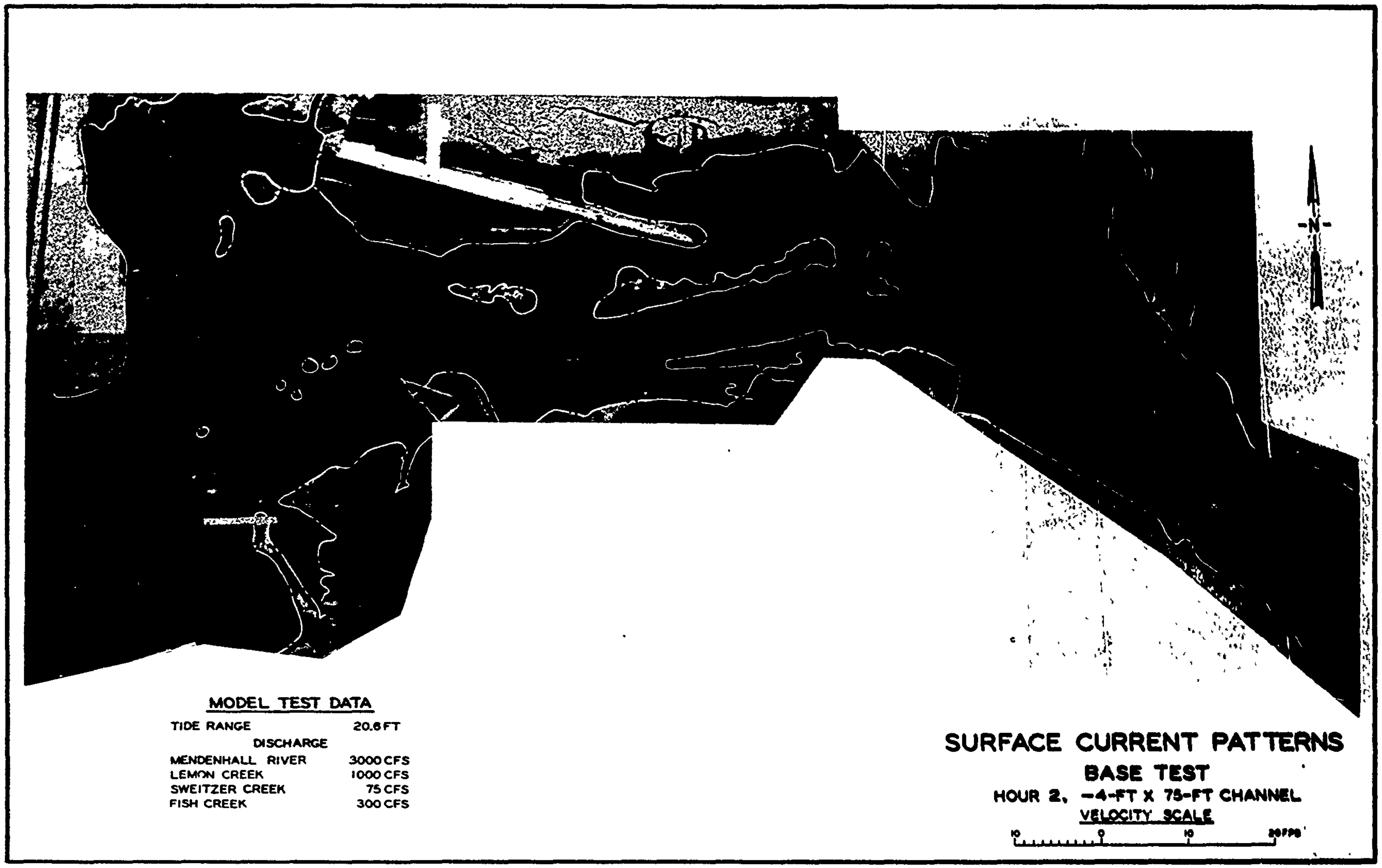

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 1, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
N

PHOTO 9



MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
N
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 2, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 10

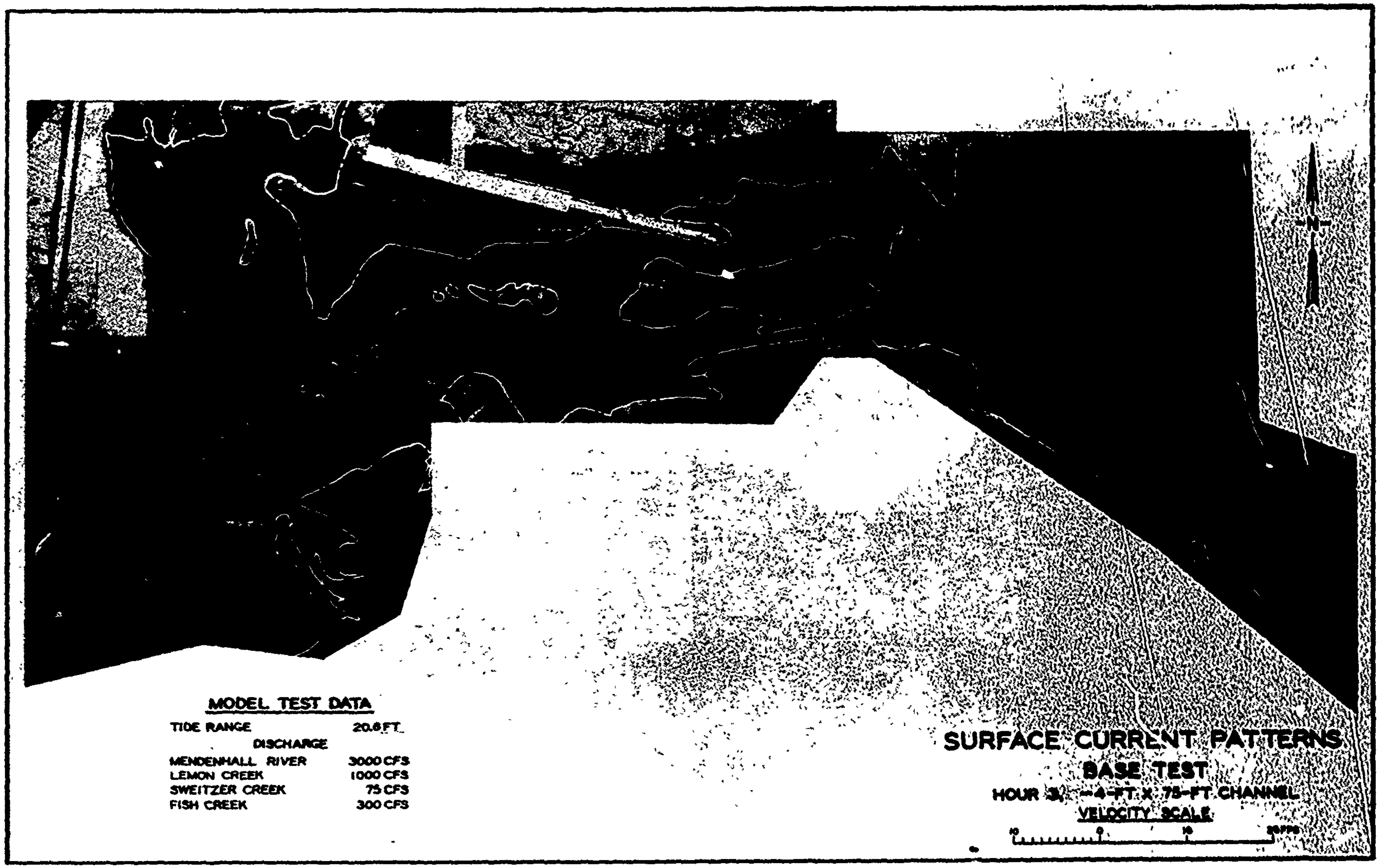

N
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 3, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10
0
10
20 FPS

PHOTO 11

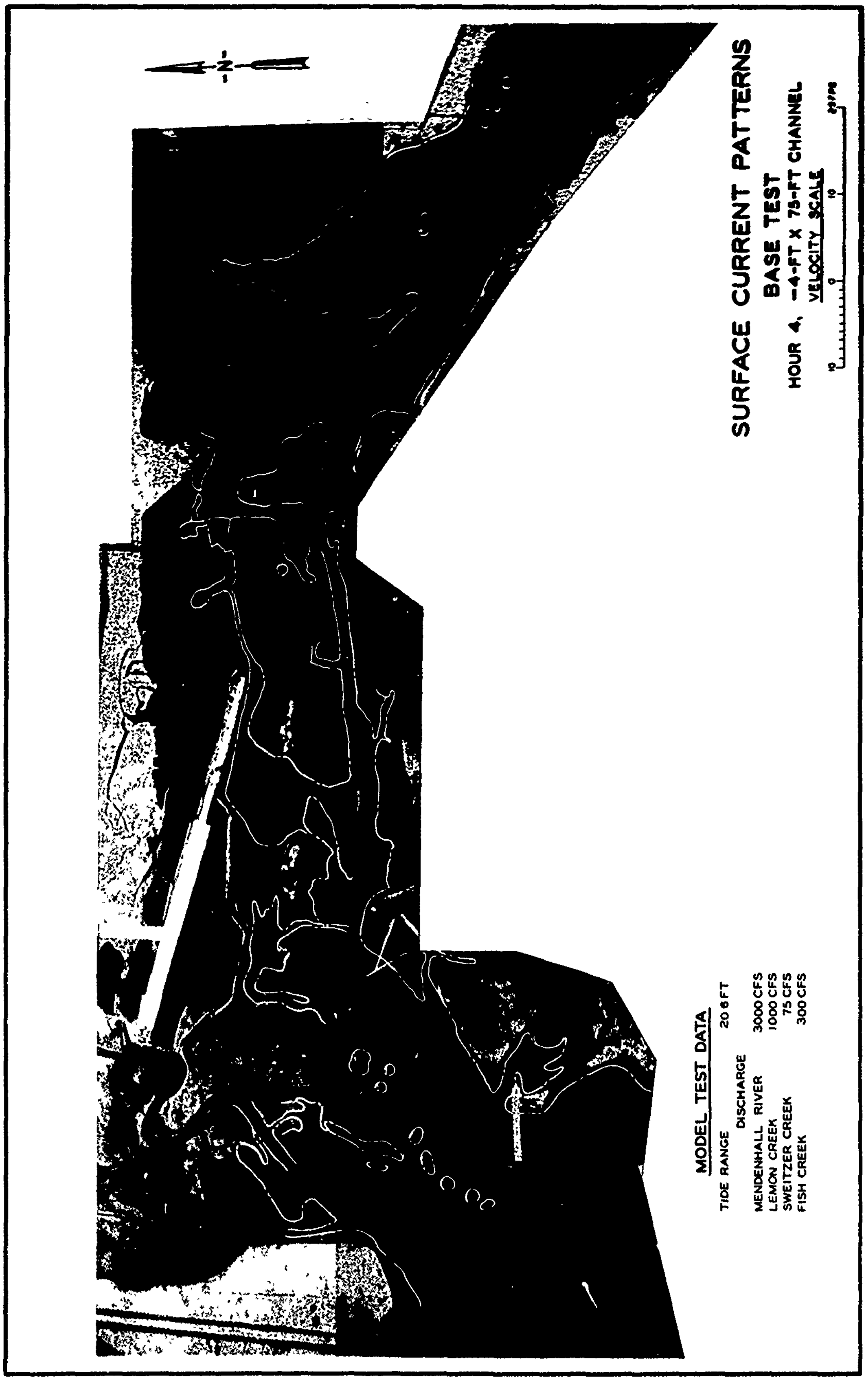

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 4, −4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 12

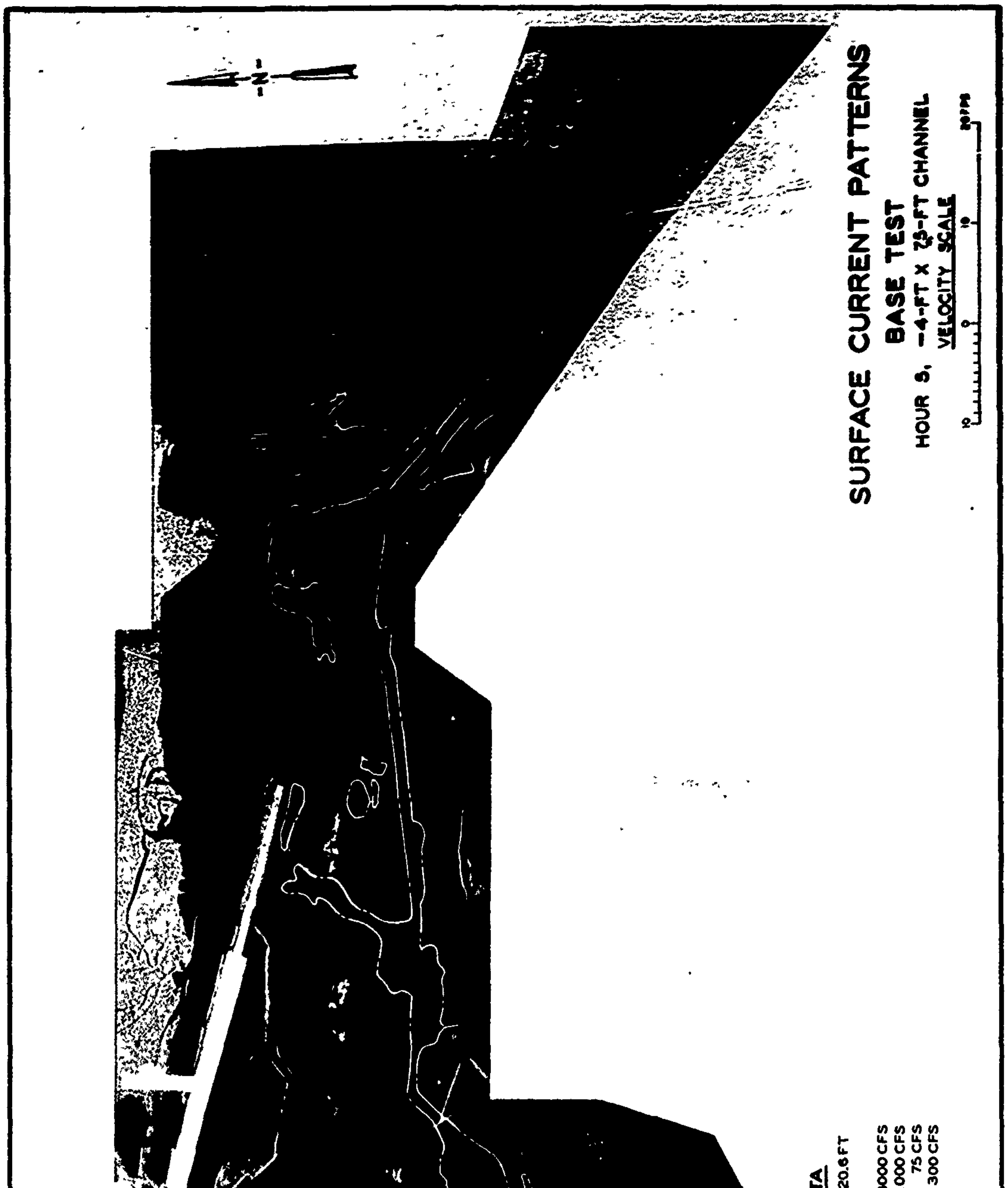

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 5, —4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 13

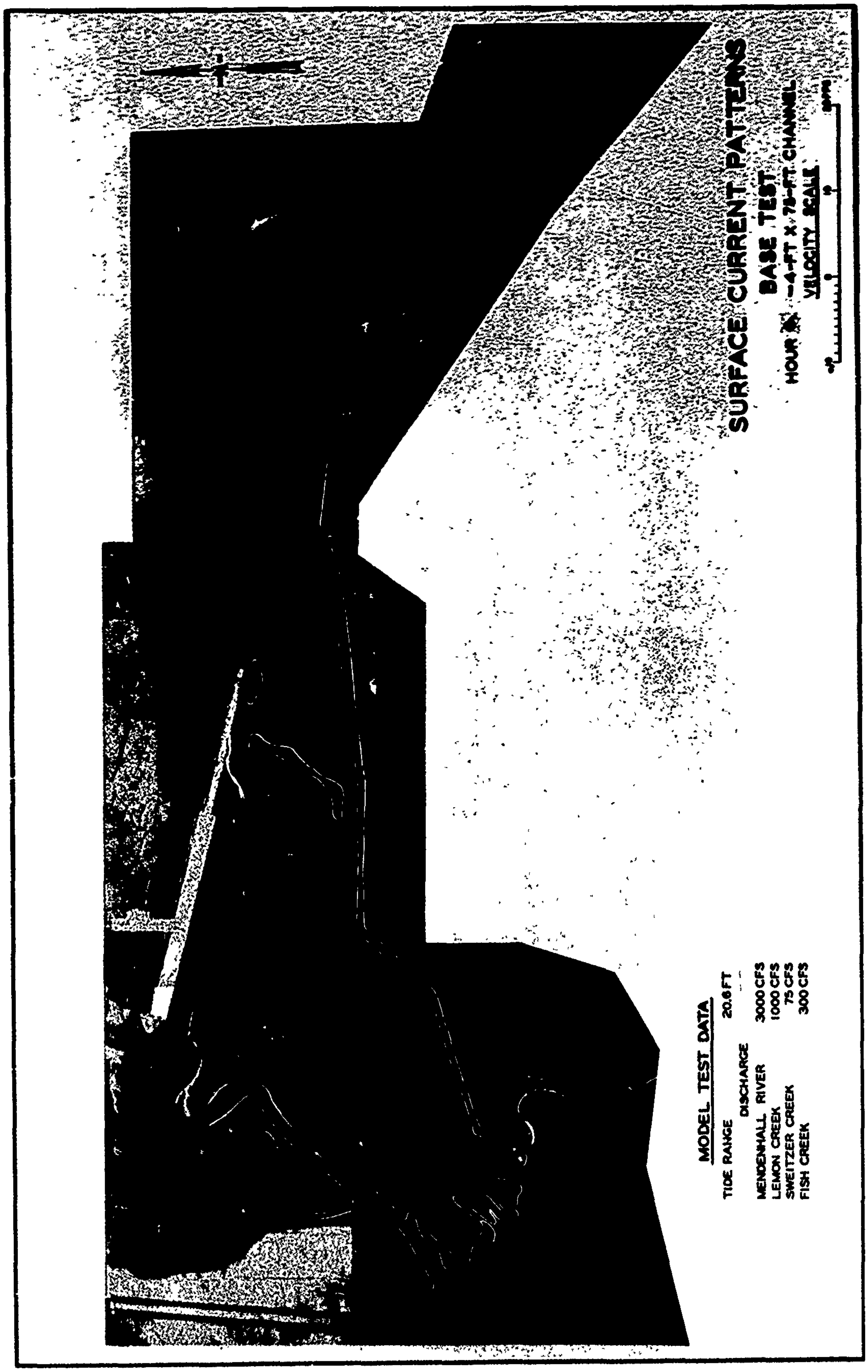

SURFACE CURRENT PATTERNS
BASE TEST
HOUR
-4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 14

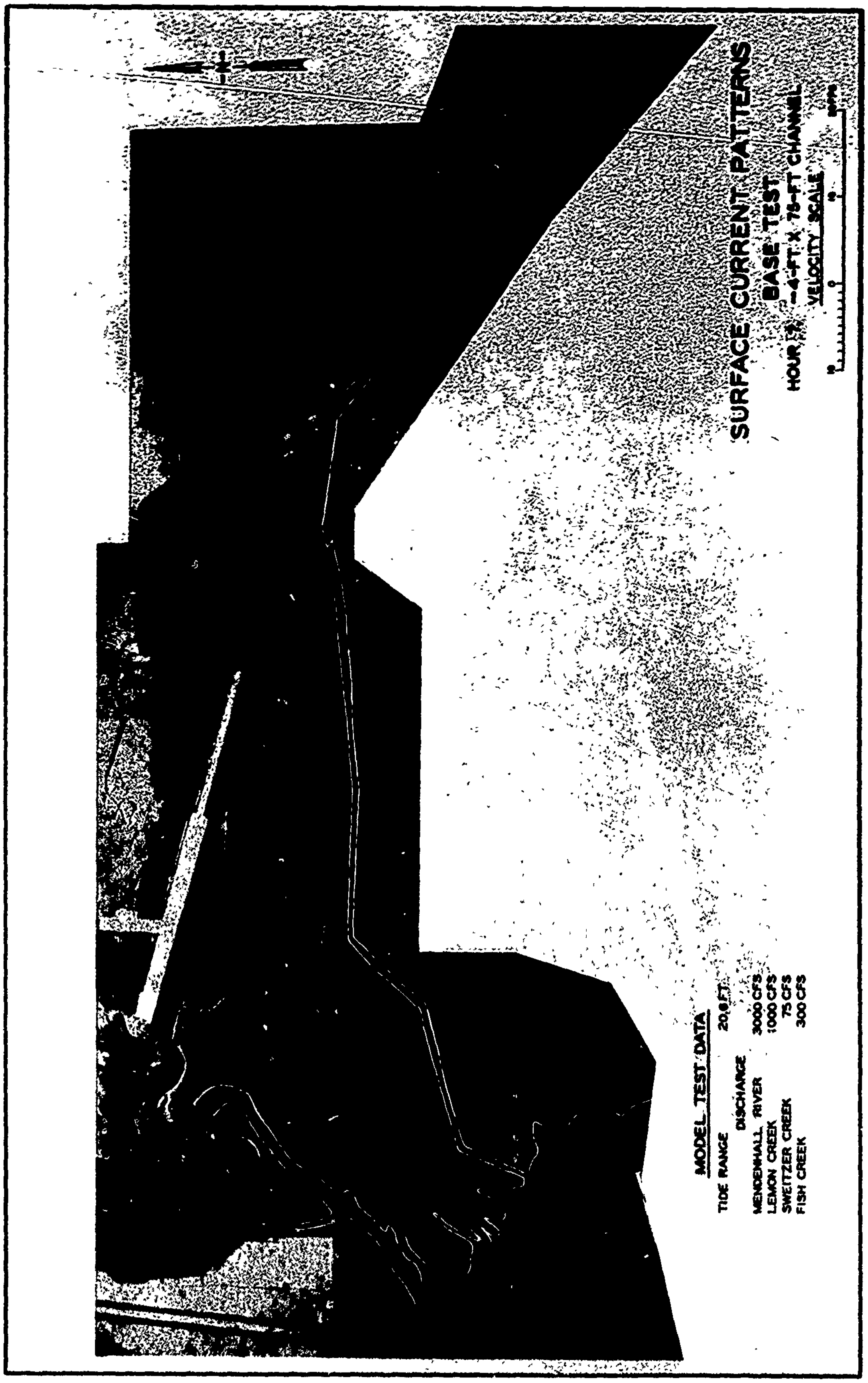

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 15, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 15

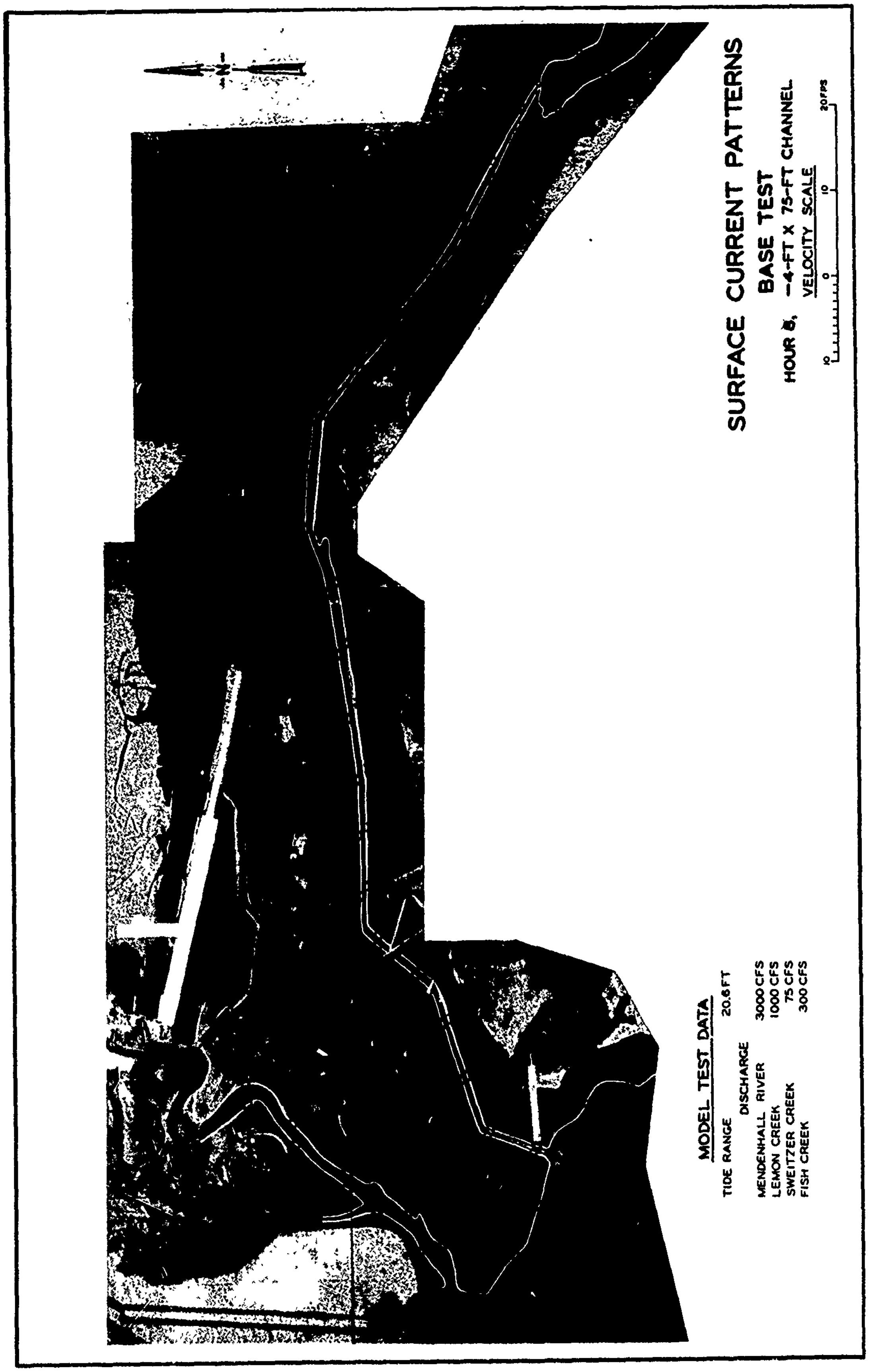

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 8, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
N

PHOTO 16

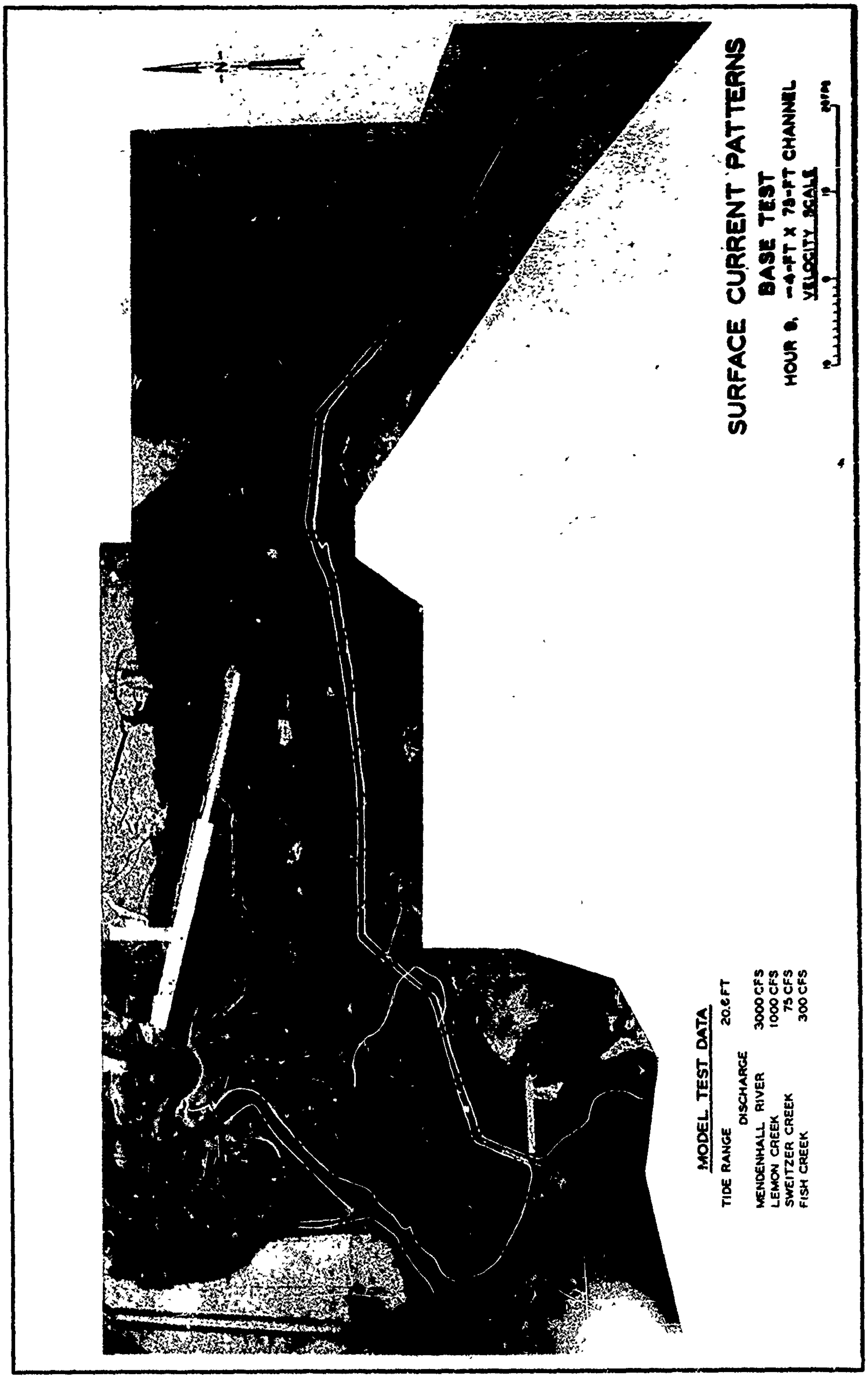

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 6, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 17

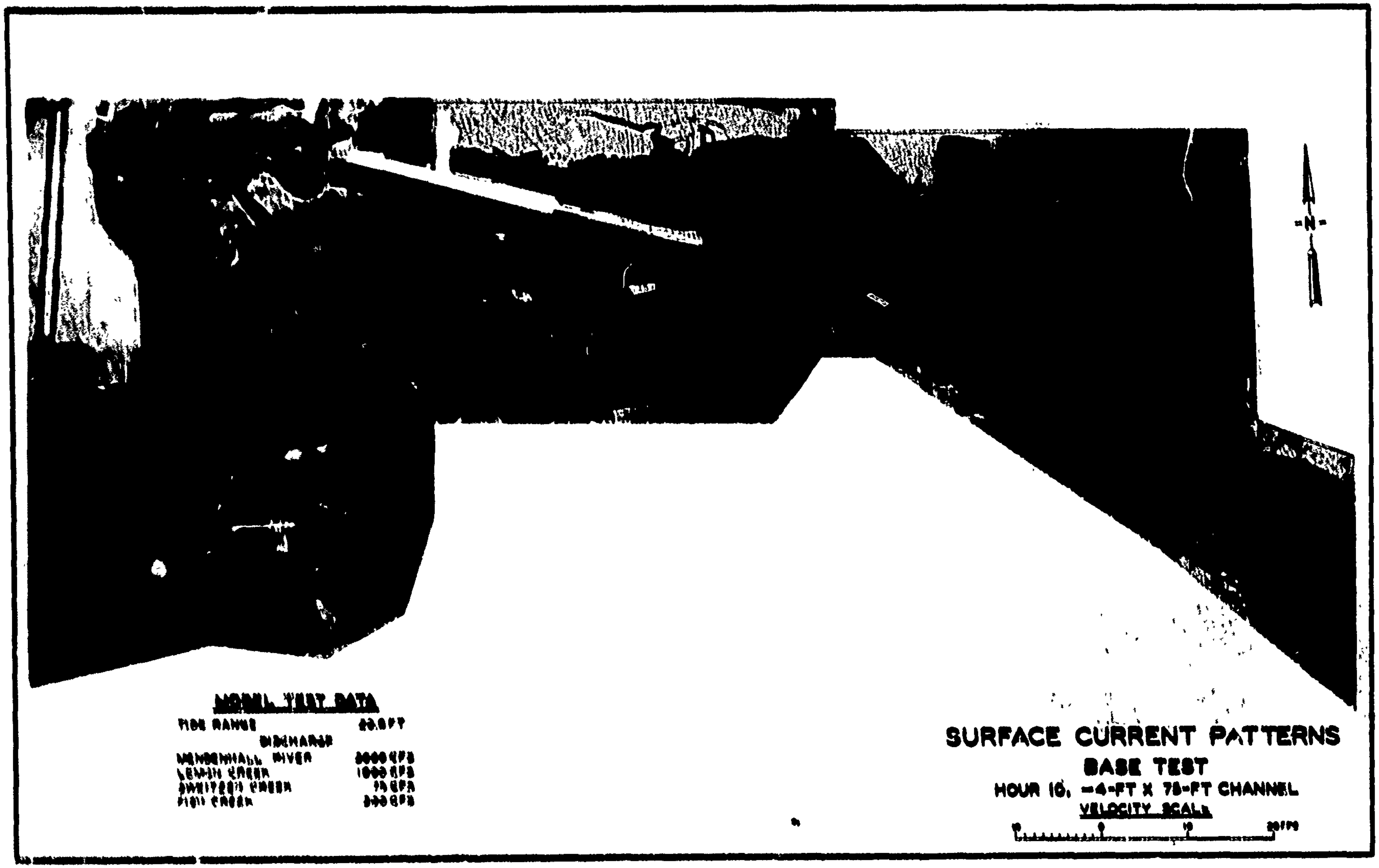
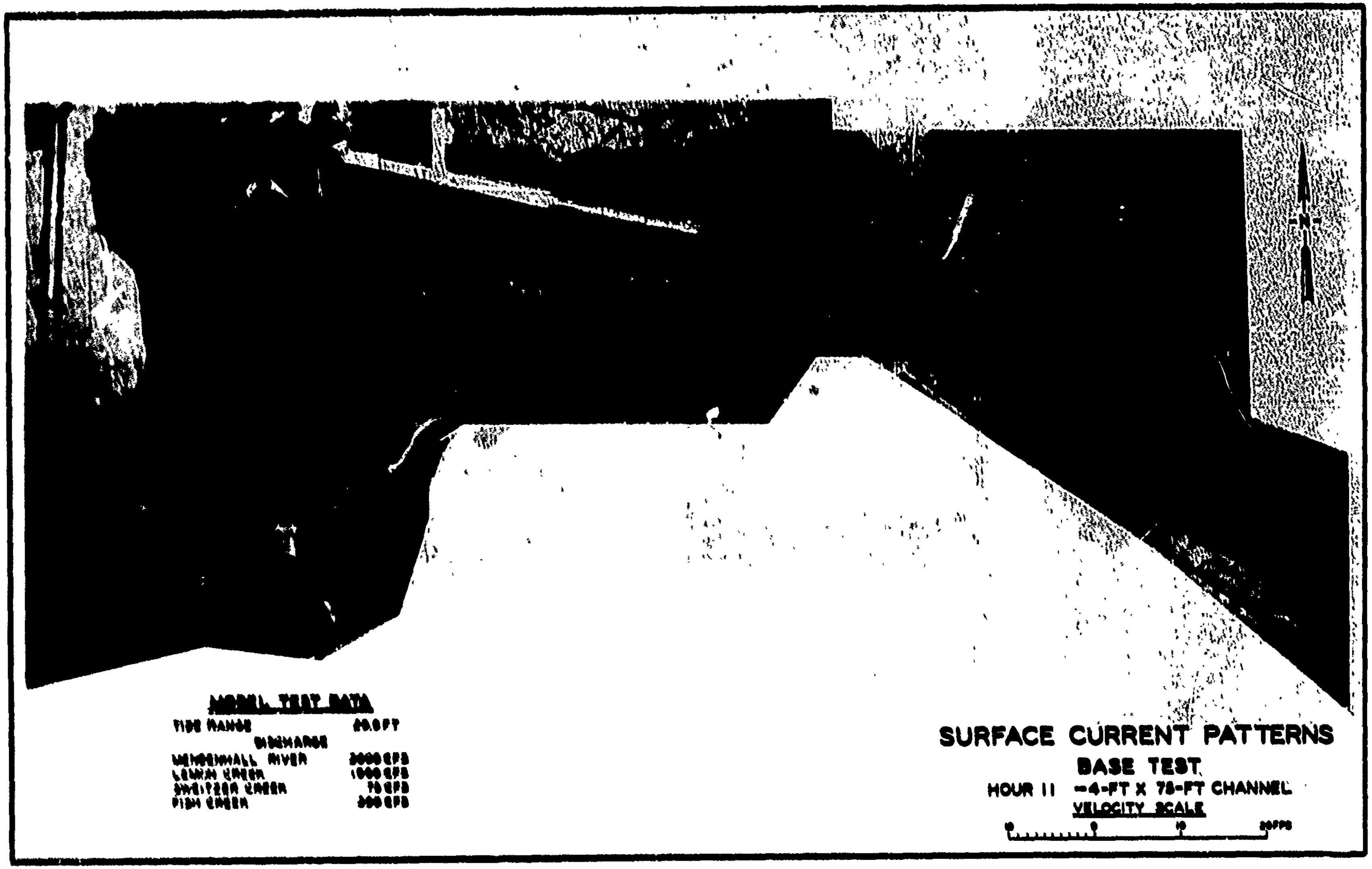
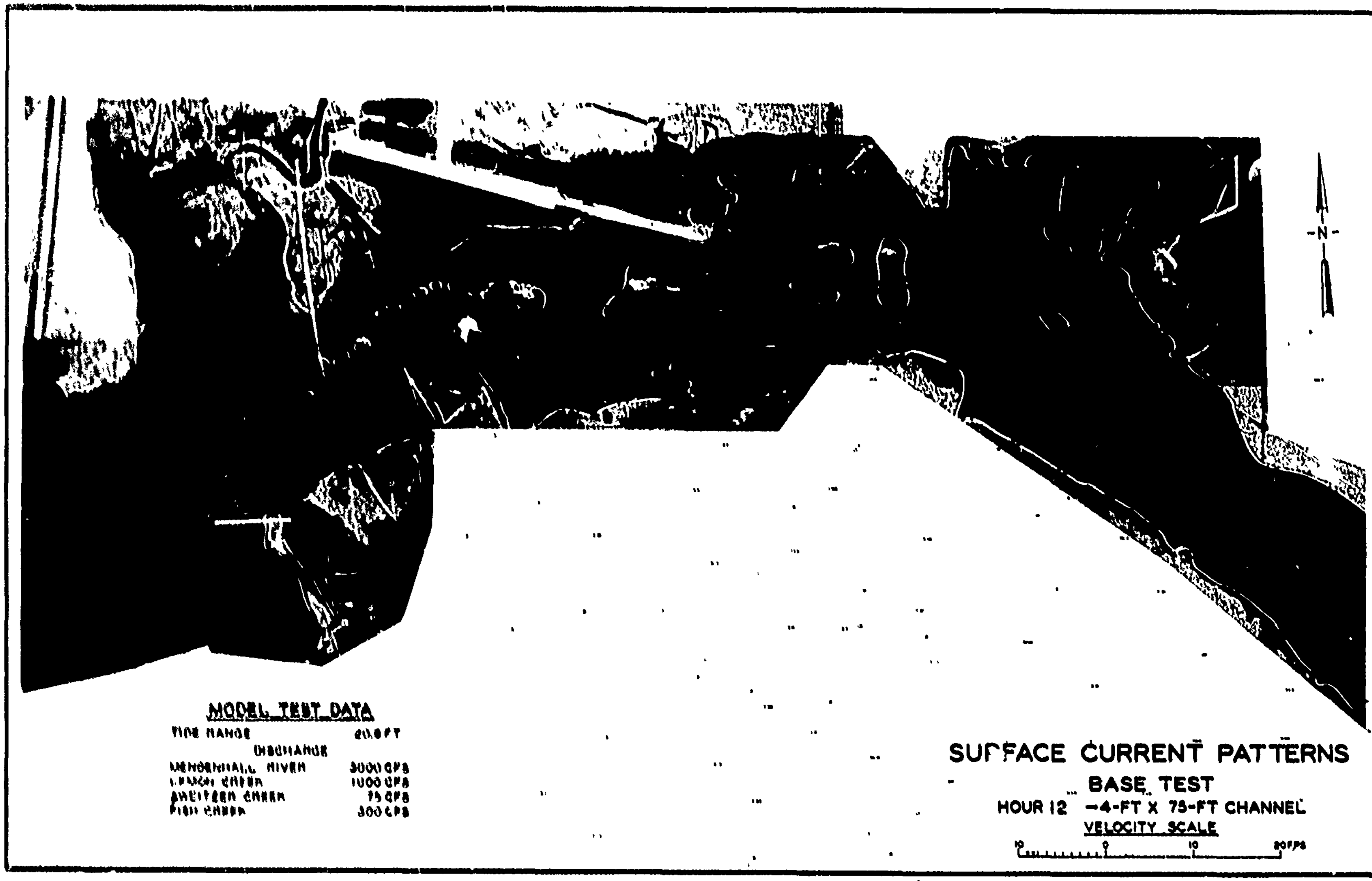

N
MODEL TEST DATA
TIDE RANGE
DISCHARGE
MENDENHALL RIVER
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 10, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10
0
10
20 FPS

PHOTO 35


SURFACE CURRENT PATTERNS
BASE TEST
HOUR 11 -4-FT X 75-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE
DISCHARGE
MENDENHALL RIVER



N
MODEL TEST DATA
TIDE RANGE
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 12 -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

MODEL TEST DATA

TIDE RANGE	[illegible] FT
DISCHARGE	
MENDENHALL RIVER	[illegible]000 CFS
LEMON CREEK	1000 CFS
SWITZER CREEK	[illegible] CFS
FISH CREEK	[illegible]00 CFS

SURFACE CURRENT PATTERNS

BASE TEST

HOUR 13, −4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20FPS

MODEL TEST DATA

TIDE RANGE	20.0 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

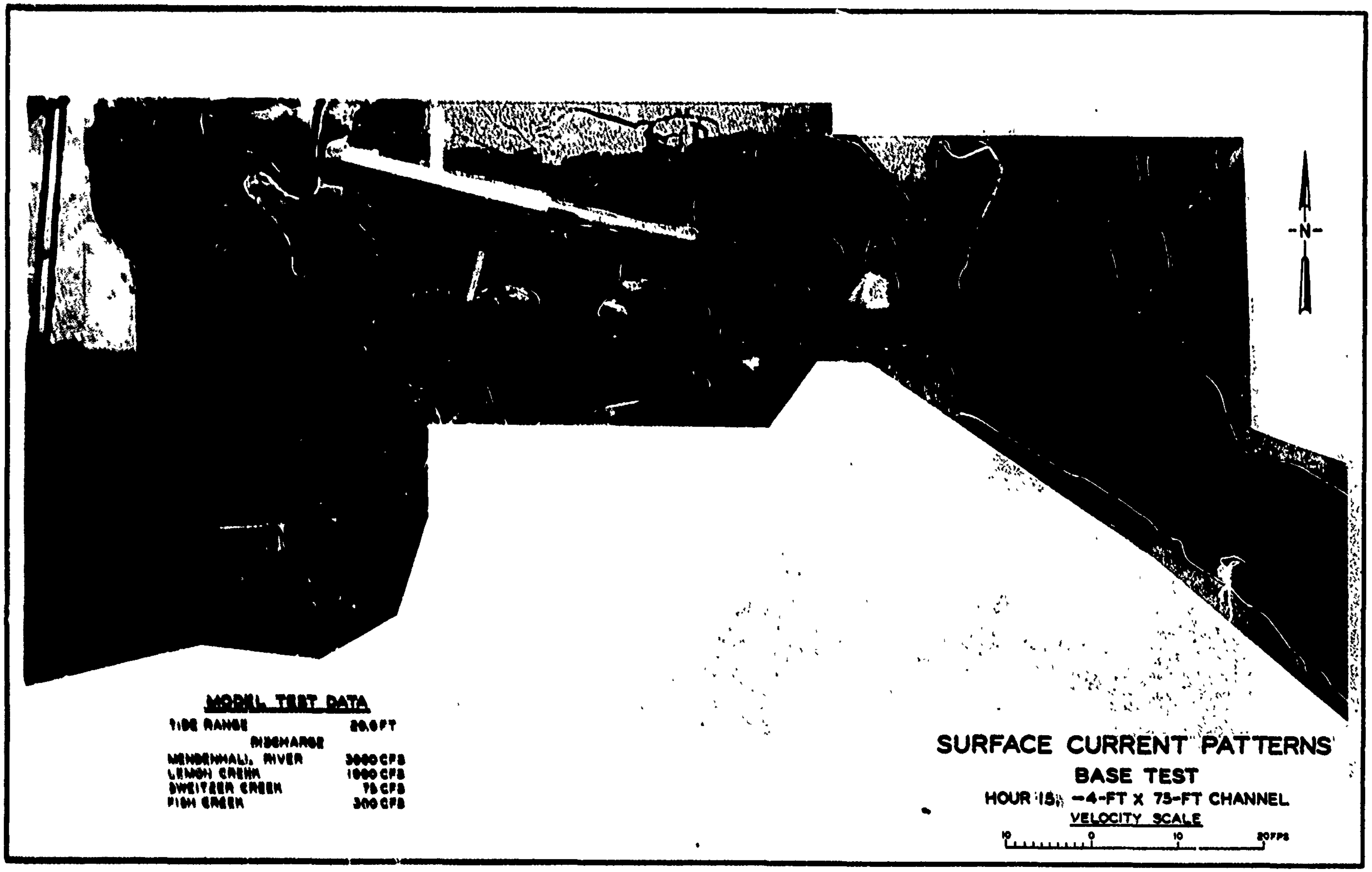
BASE TEST

HOUR 14, −4-FT X 75-FT CHANNEL

VELOCITY SCALE

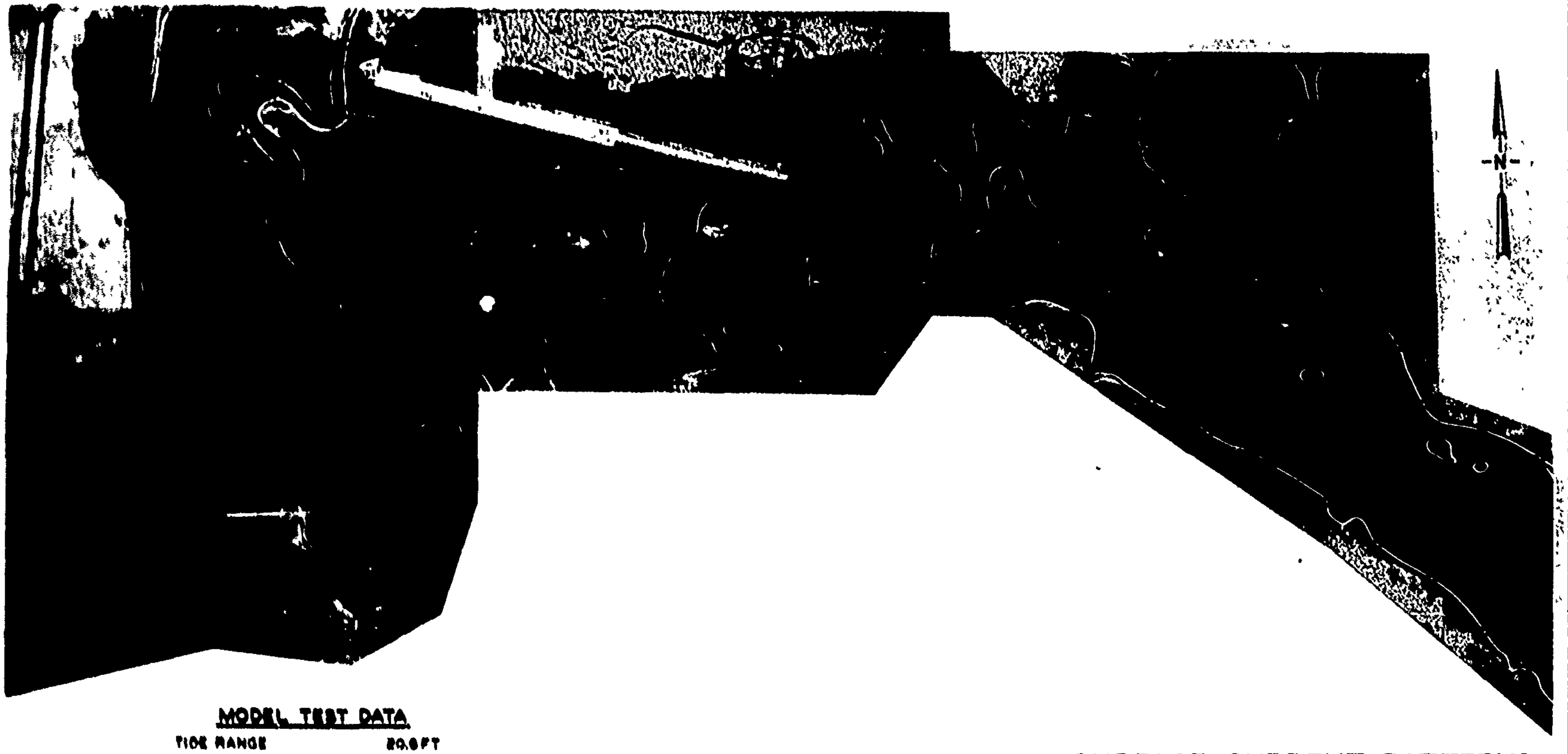
10 0 10 20 FPS

PHOTO 22



N
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 15, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 23



MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 16, −4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 24

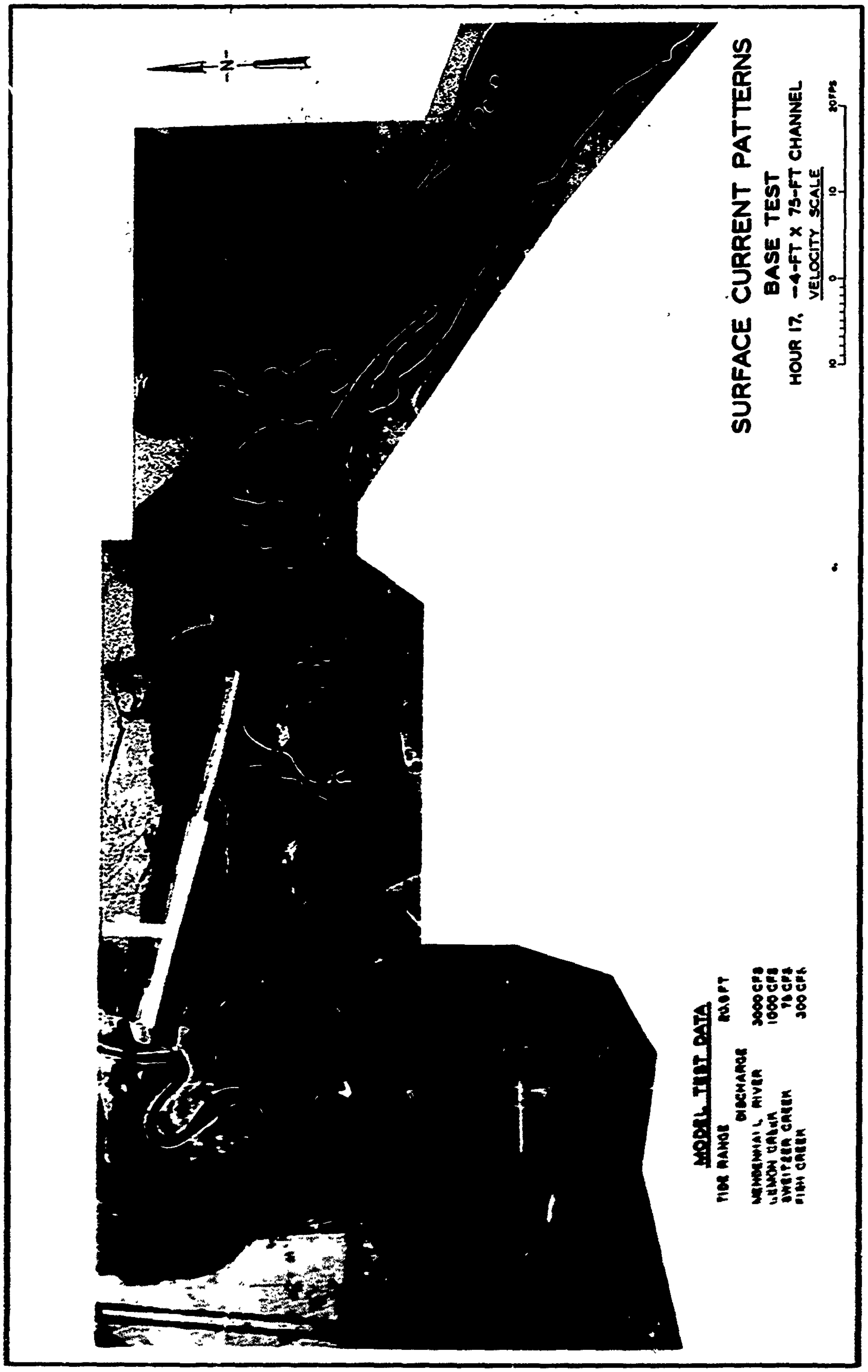

N
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 17, −4-FT X 75-FT CHANNEL
VELOCITY SCALE
10
0
10
20 FPS
MODEL TEST DATA
TIDE RANGE
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 25

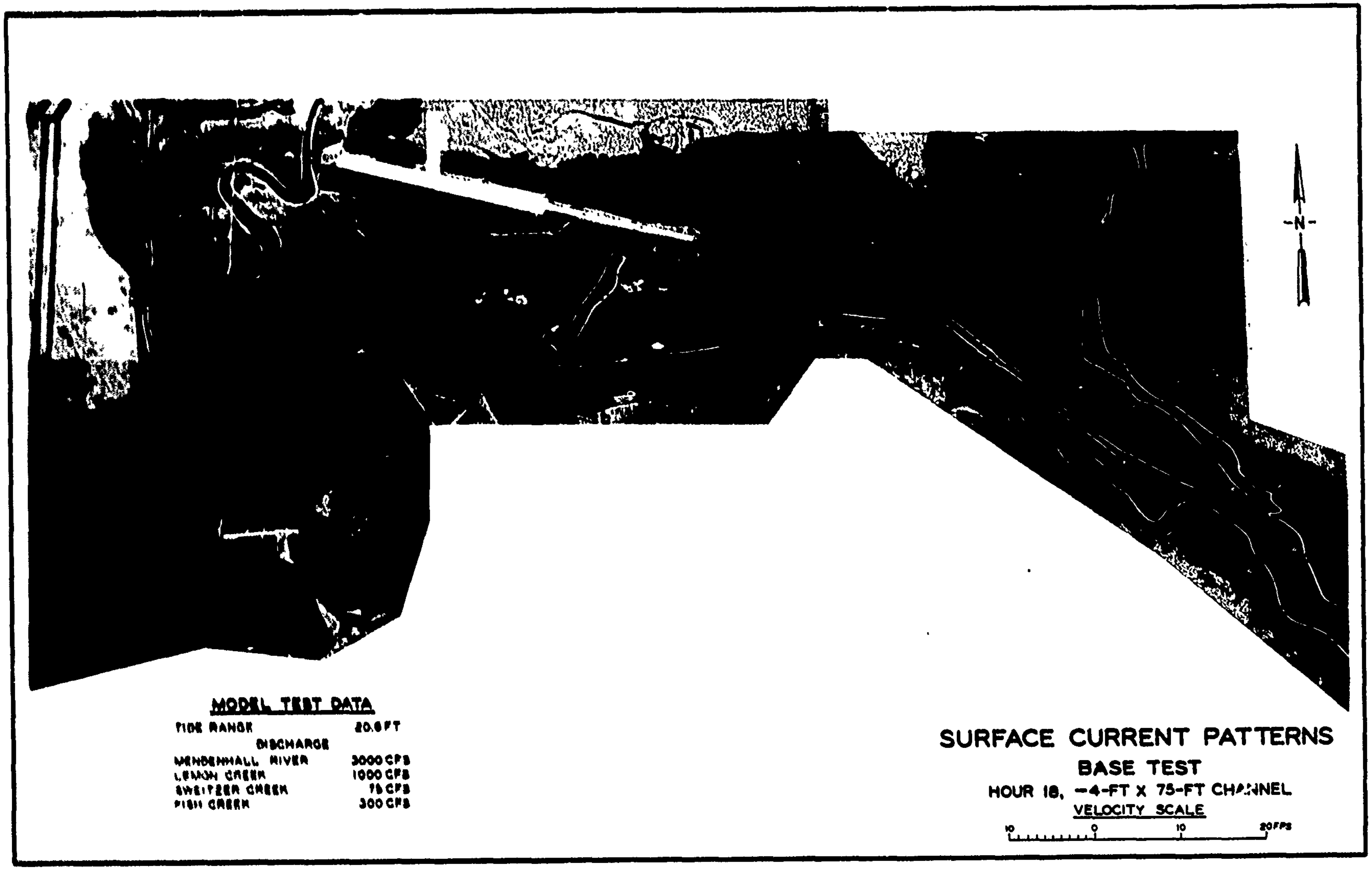

N
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 18, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 26

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS
BASE TEST
HOUR 19, −4-FT X 75-FT CHANNEL

VELOCITY SCALE
10 0 10 20 FPS

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

BASE TEST

HOUR 20, −4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 28

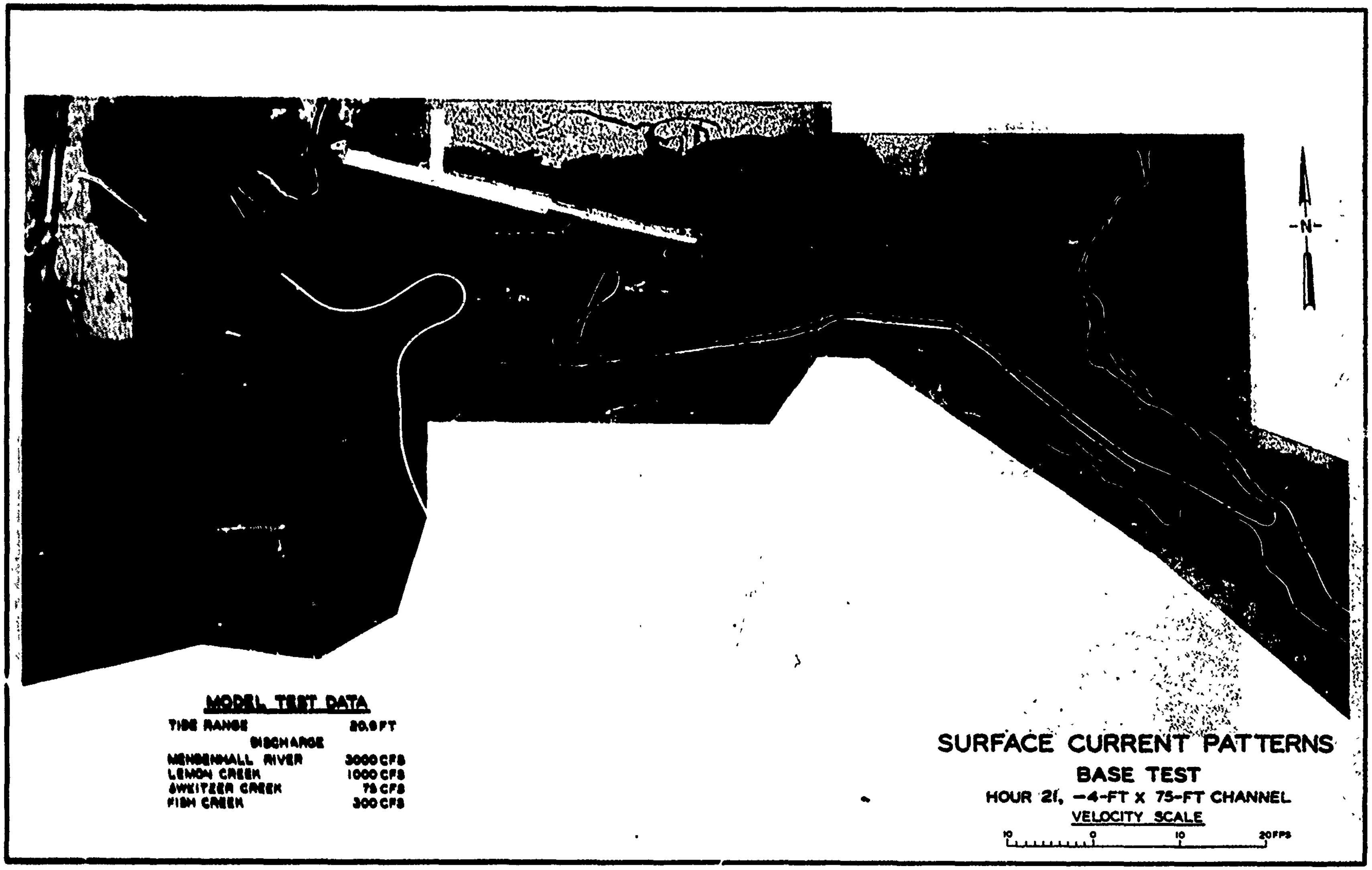

N
MODEL TEST DATA
TIDE RANGE 20.9 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 21, −4-FT x 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 29

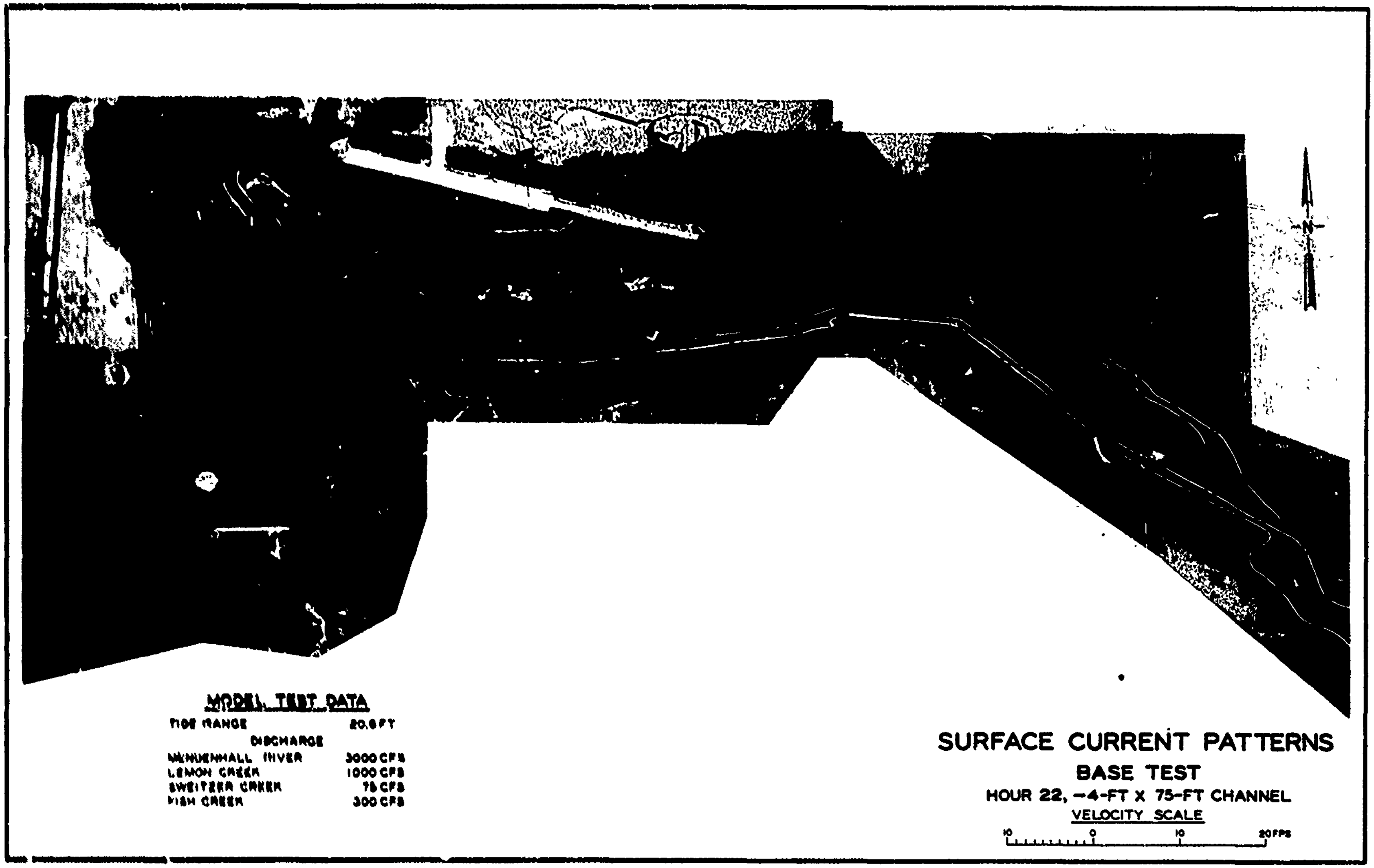
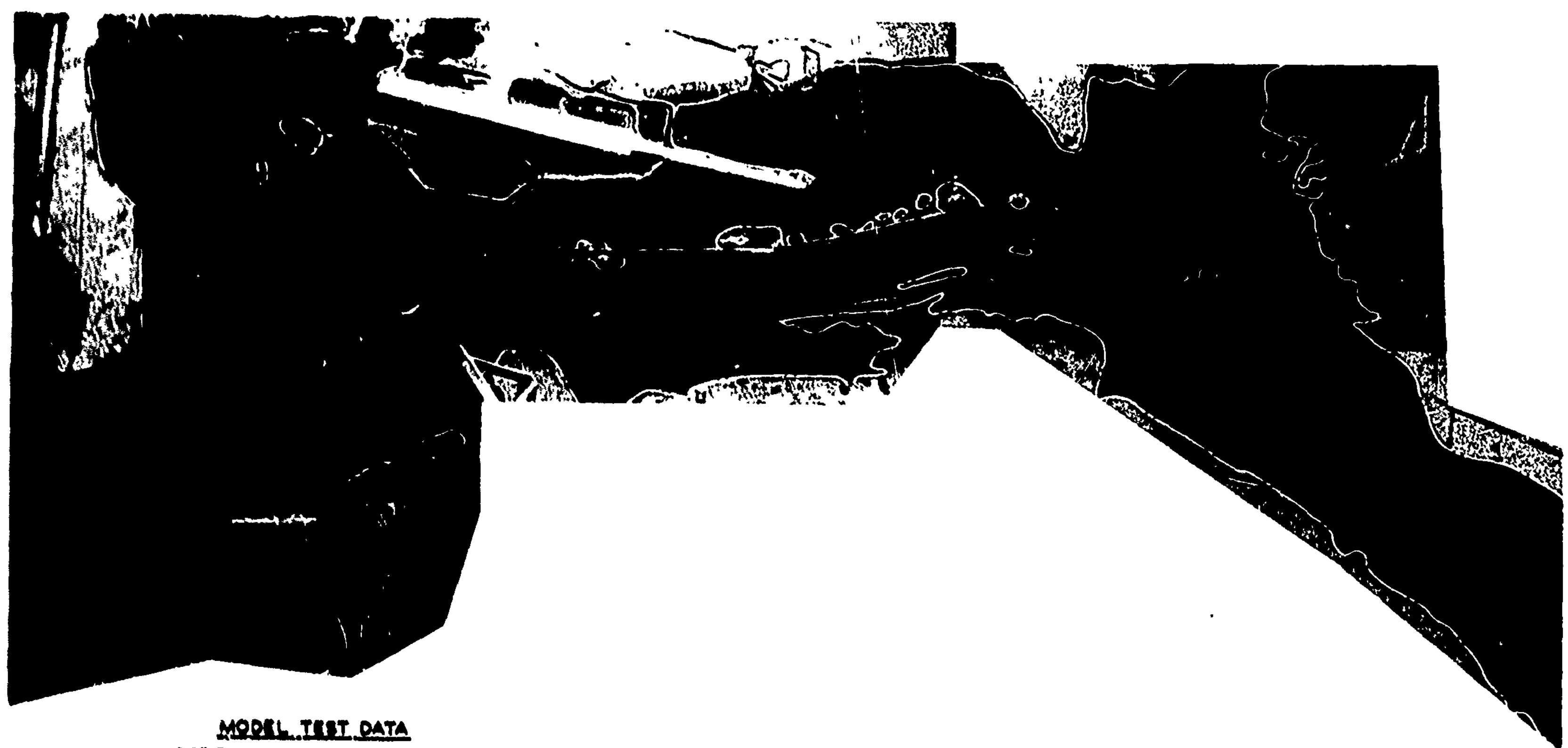

MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
N
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 22, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 30



MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS
PLAN I
HOUR 14, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 33

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

BASE TEST

HOUR 23, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 31

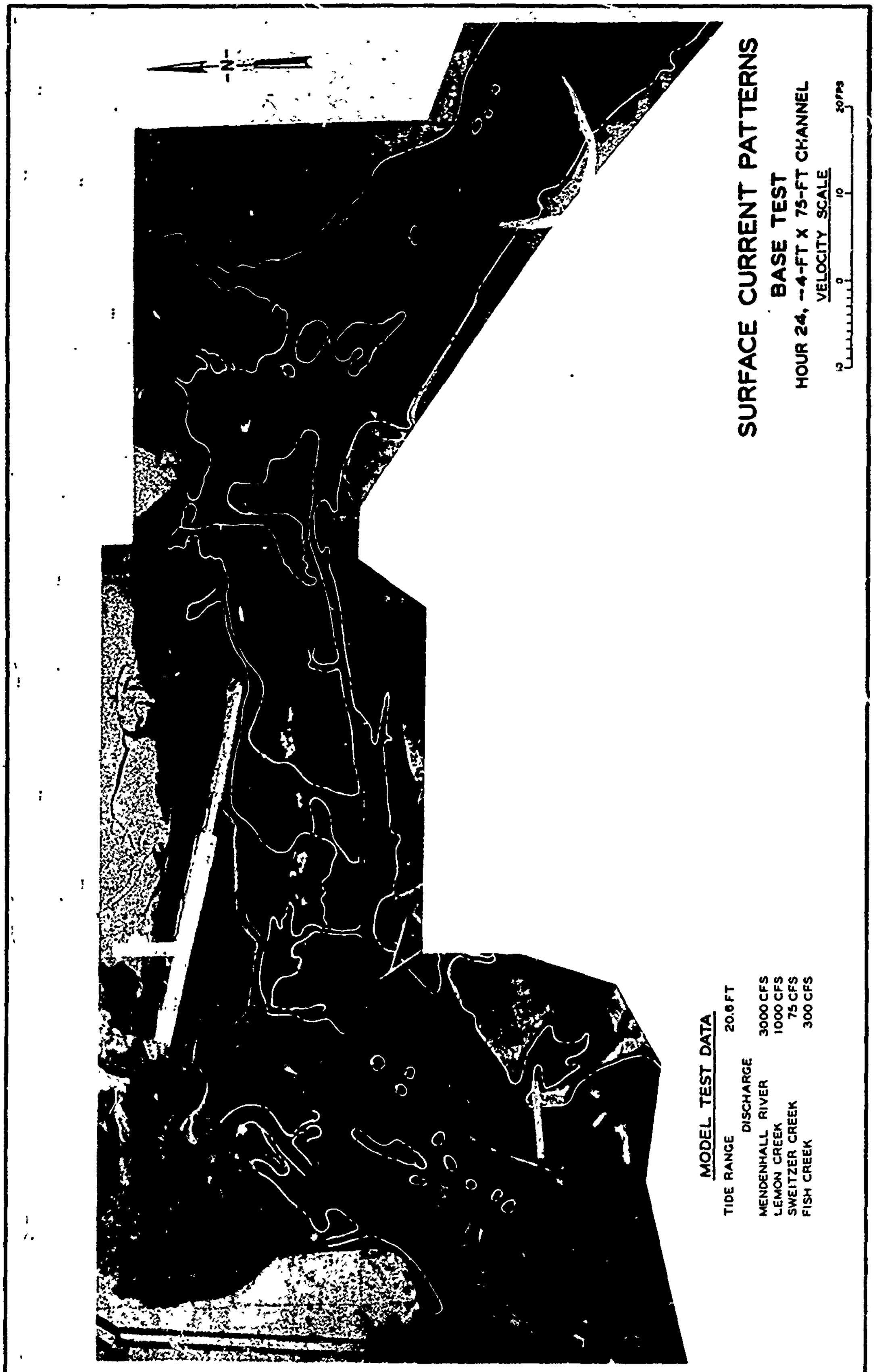

N
SURFACE CURRENT PATTERNS
BASE TEST
HOUR 24, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 32

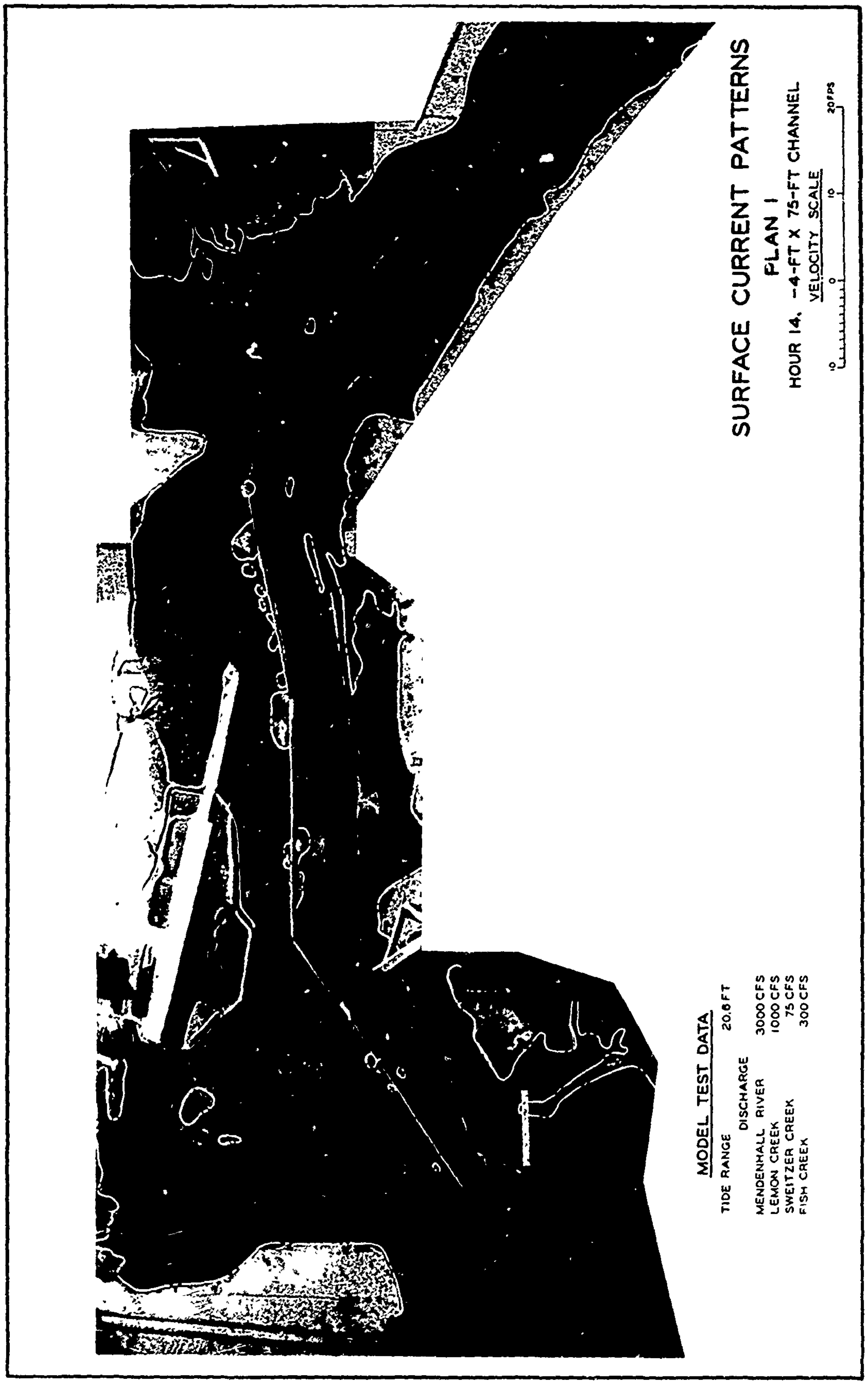

SURFACE CURRENT PATTERNS
PLAN 1
HOUR 14, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 33

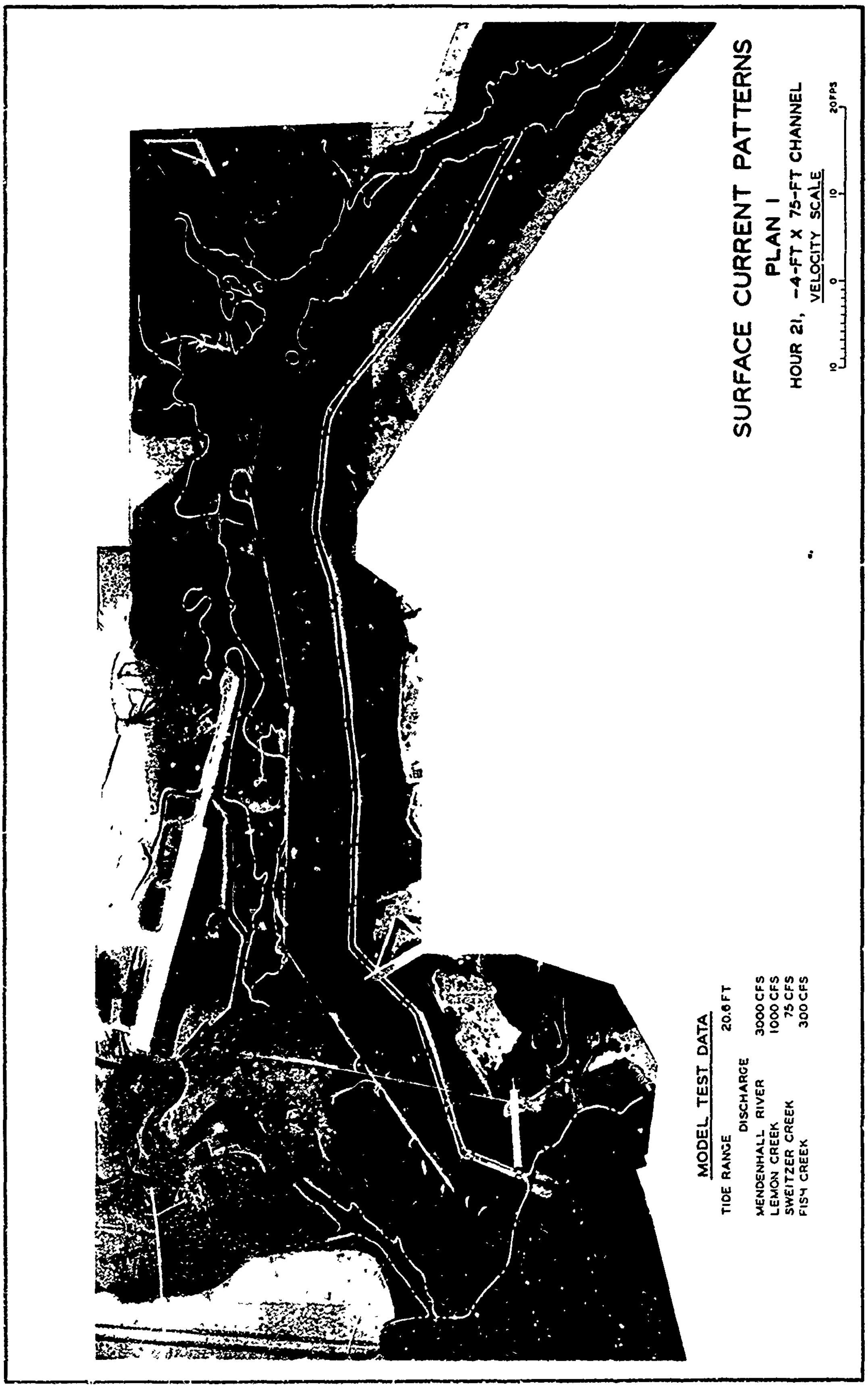

SURFACE CURRENT PATTERNS
PLAN 1
HOUR 21, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 34

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 1

HOUR 4, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 35

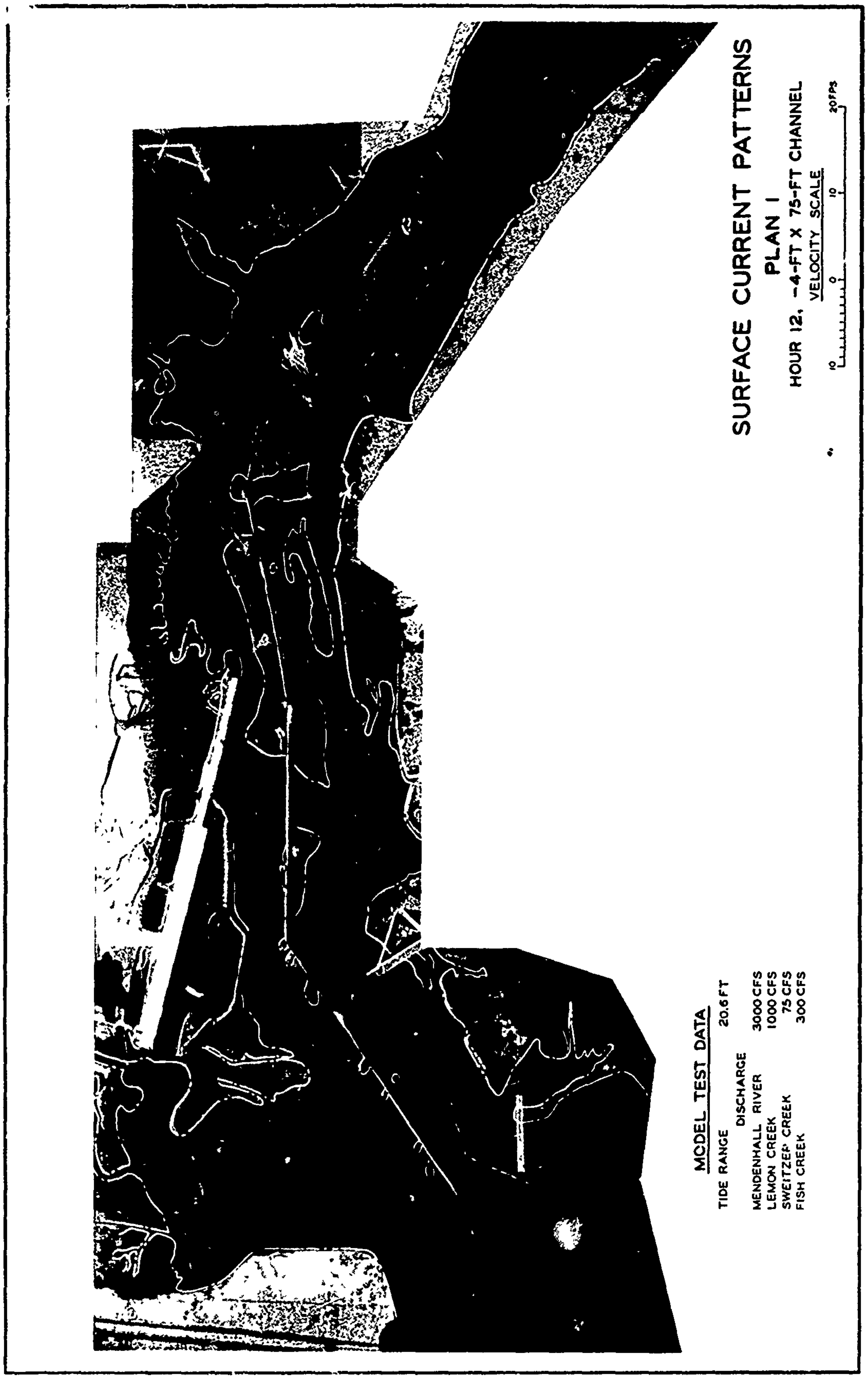

SURFACE CURRENT PATTERNS
PLAN I
HOUR 12, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 36

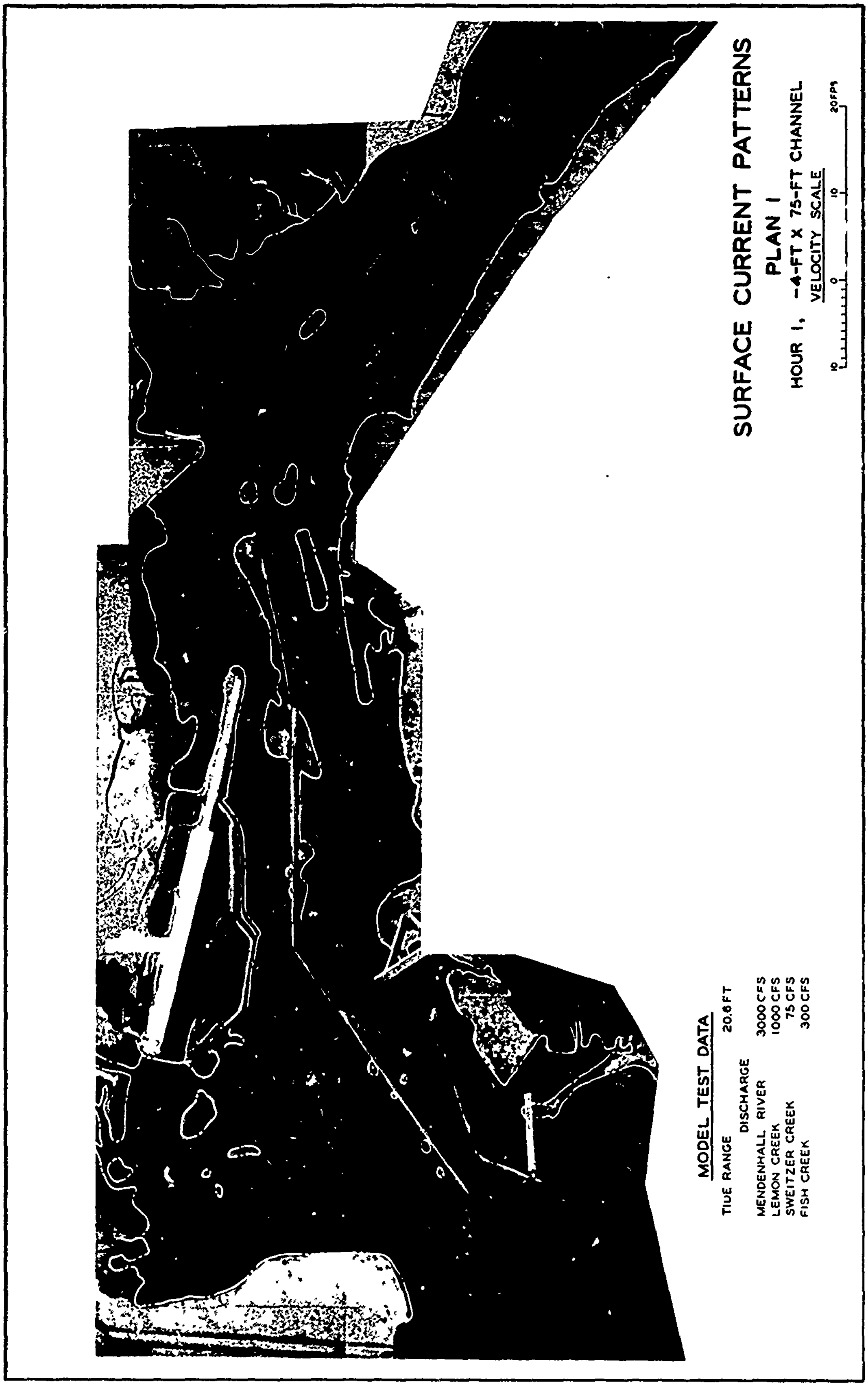
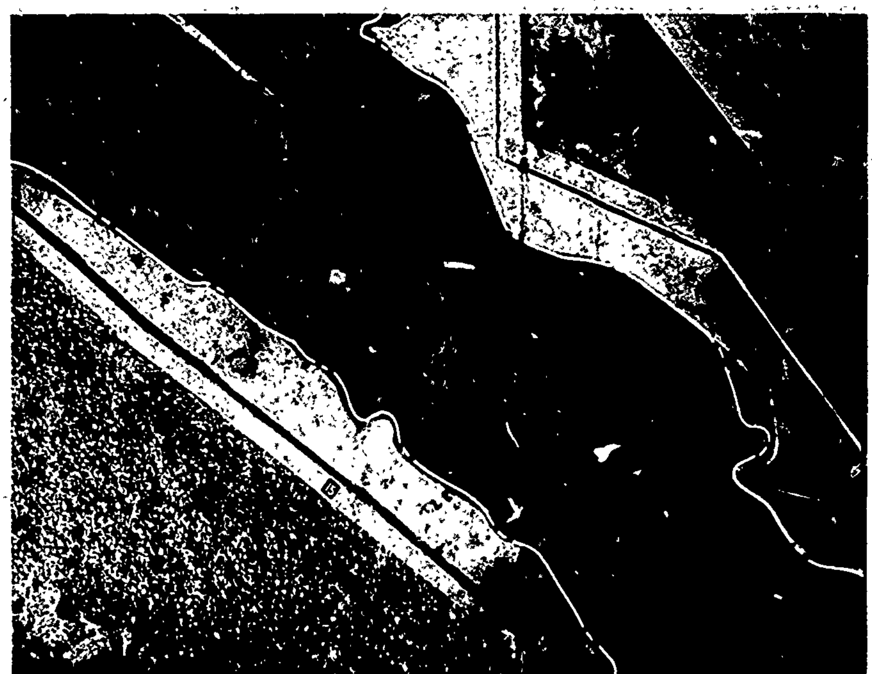

SURFACE CURRENT PATTERNS
PLAN 1
HOUR 1, -4-FT X 75-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 37

HOUR 14



HOUR 15

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

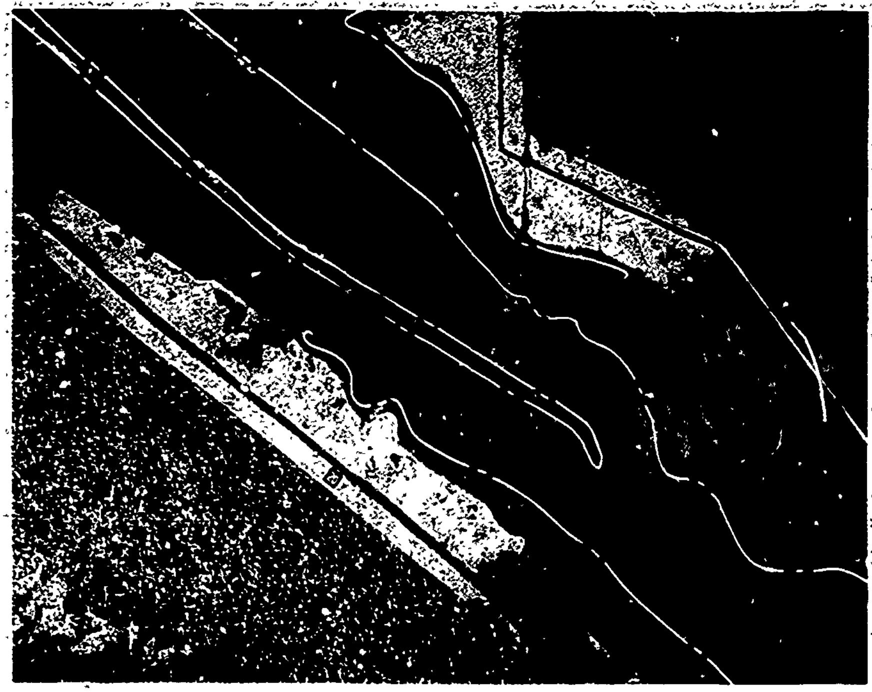
PLAN 2

HOURS 14 & 15, -4-FT X 75-FT CHANNEL

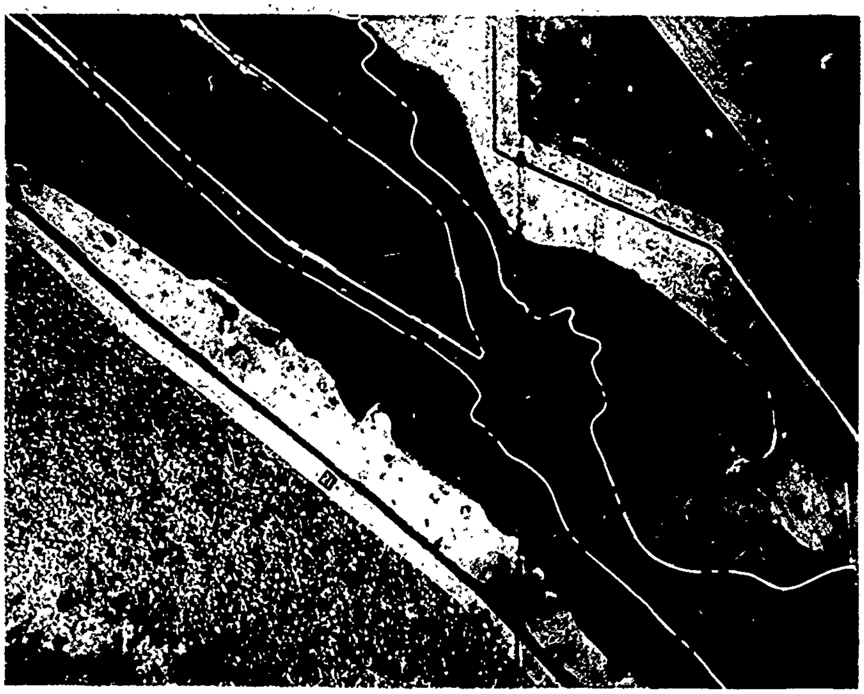
VELOCITY SCALE

0 5 10 15 FPS

PHOTO 38



HOUR 20



HOUR 21

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

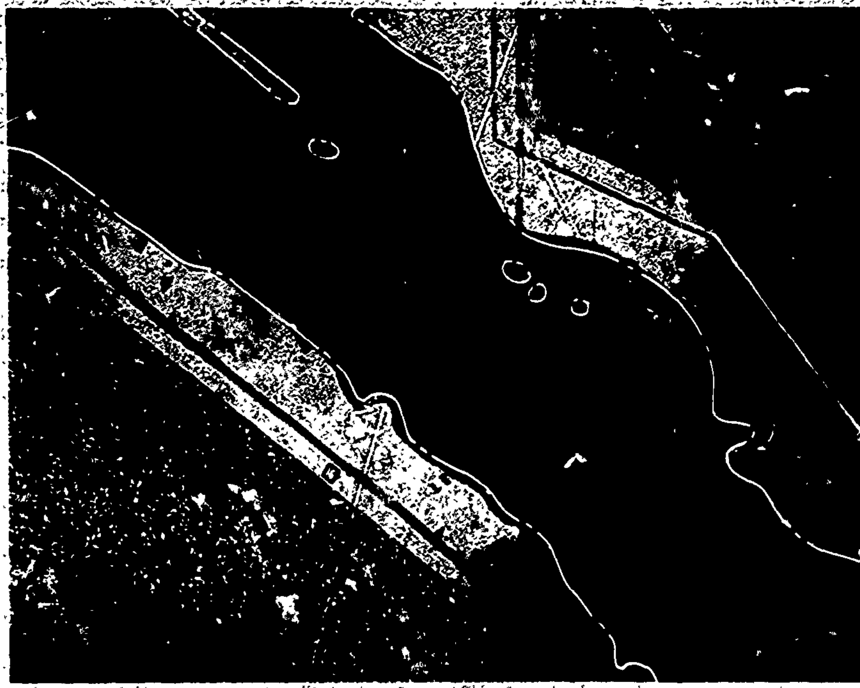
PLAN 2

HOURS 20 & 21, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

5 0 5 10 15 FPS

PHOTO 39



HOUR 16

HOUR 17

MODEL TEST DATA

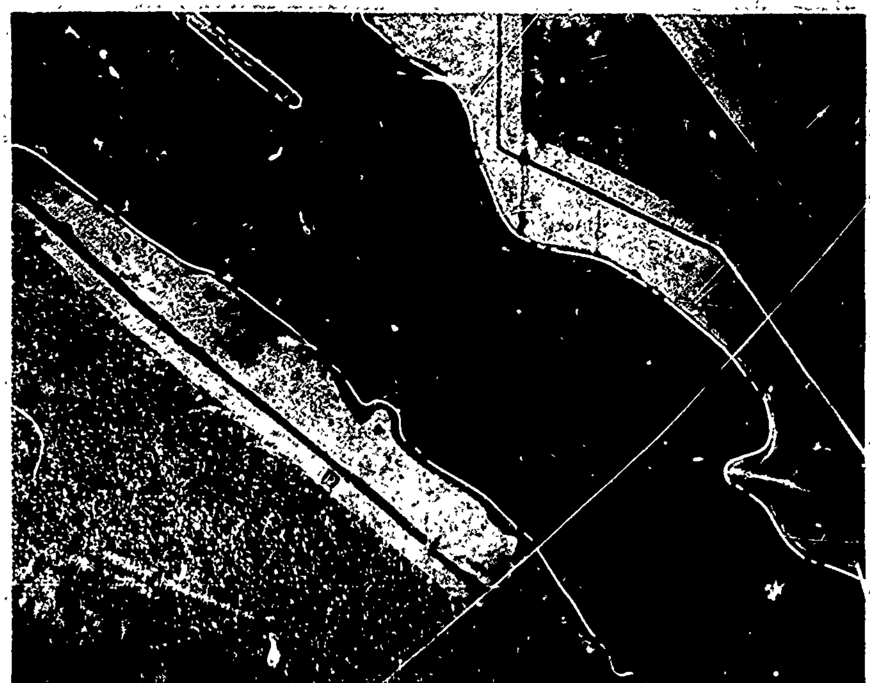
TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS
PLAN 2
HOURS 16 & 17, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

5 0 5 10 15 FPS

PHOTO 40



HOUR 12

HOUR 13

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

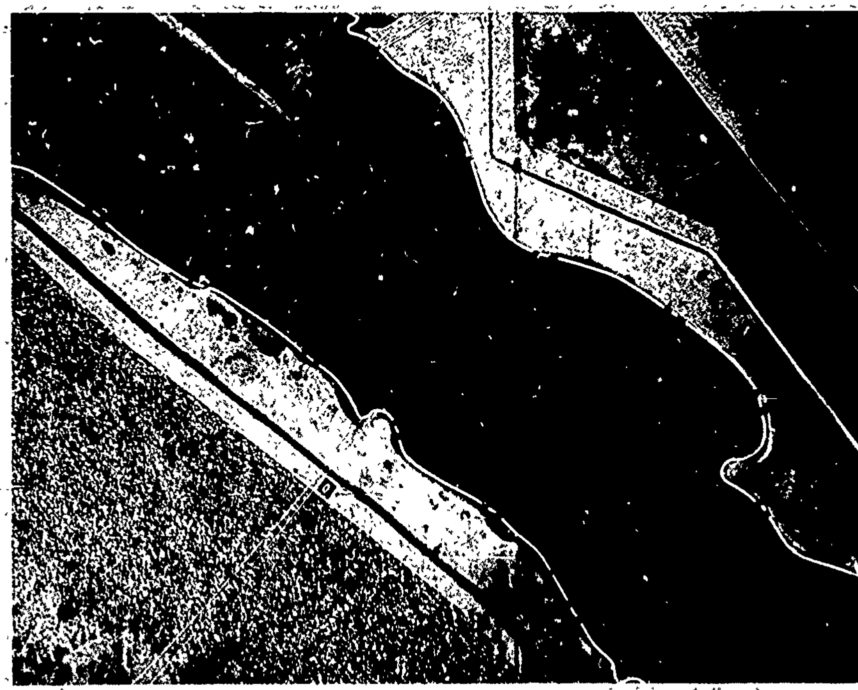
SURFACE CURRENT PATTERNS

PLAN 2

HOURS 12 & 13, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

5 0 5 10 15 FPS



HOUR 0

HOUR 1

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

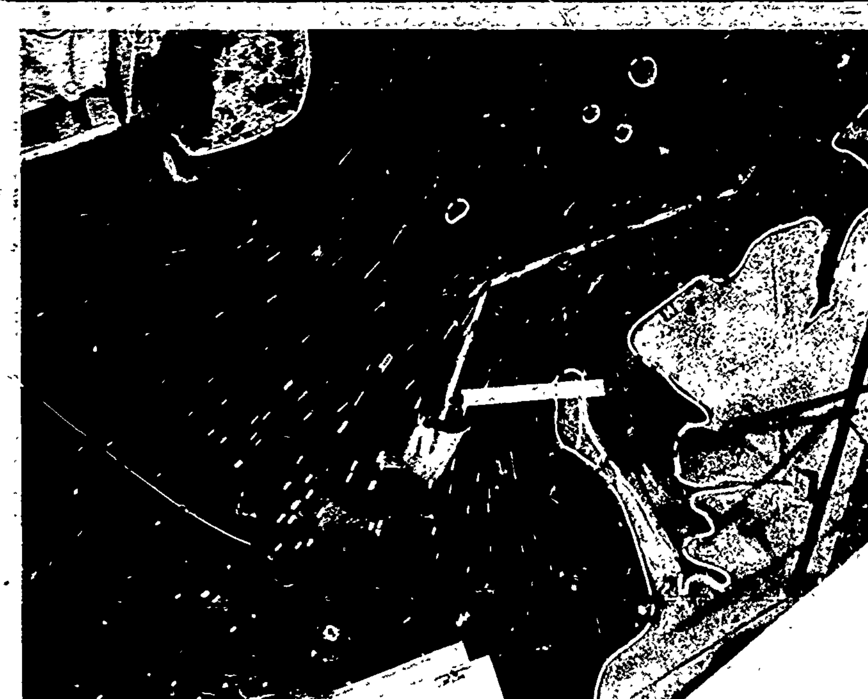
PLAN 2

HOURS 0 & 1, -4-FT X 75-FT CHANNEL

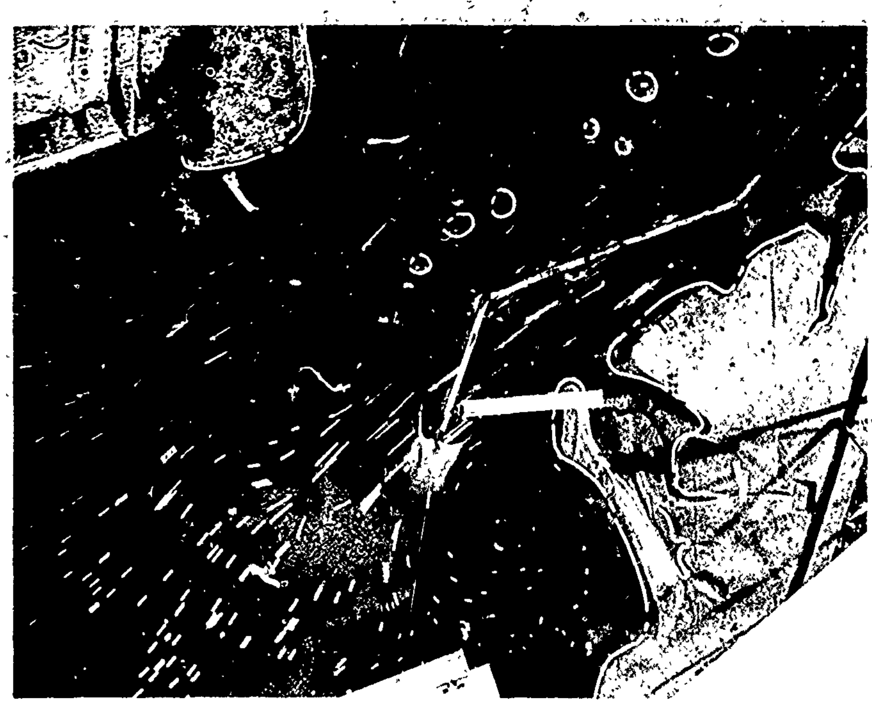
VELOCITY SCALE

5 0 5 10 15 FPS

PHOTO 42



HOUR 14



HOUR 15

MODEL TEST DATA

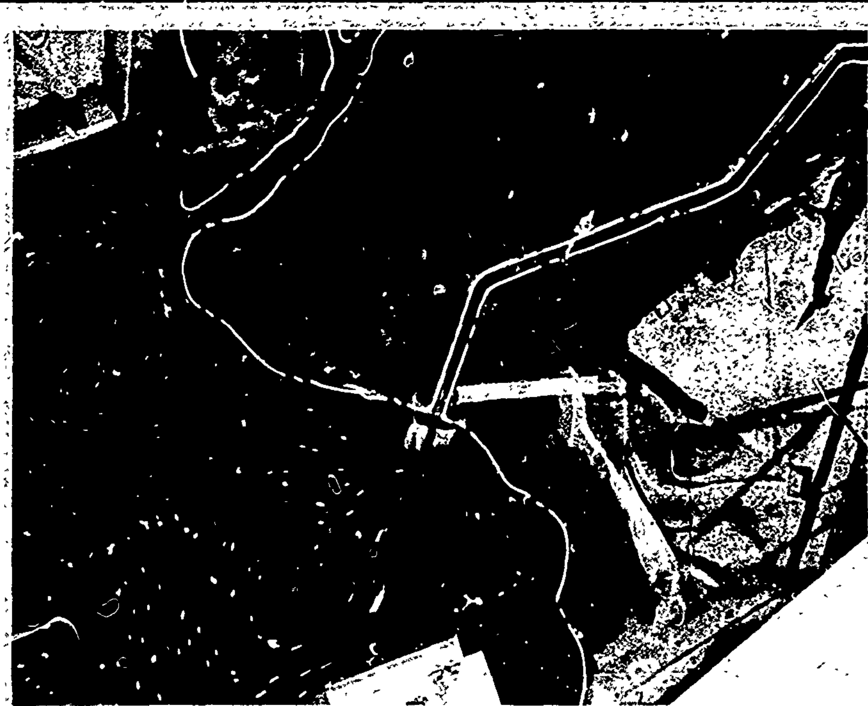
TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 3

HOURS 14 & 15, -4-FT X 75-FT CHANNEL

VELOCITY SCALE



HOUR 20

HOUR 21

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

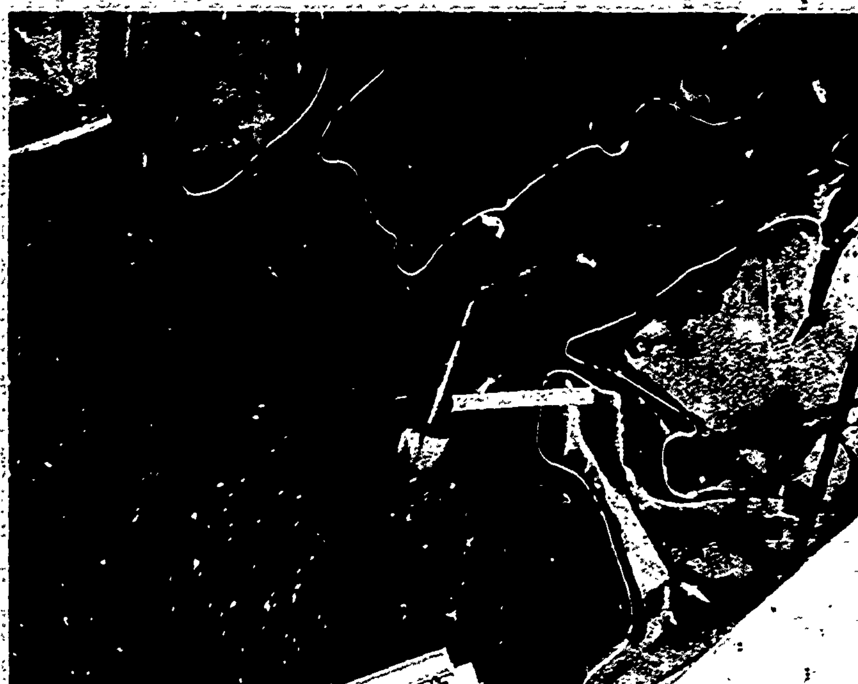
PLAN 3

HOURS 20 & 21, -4-FT X 75-FT CHANNEL

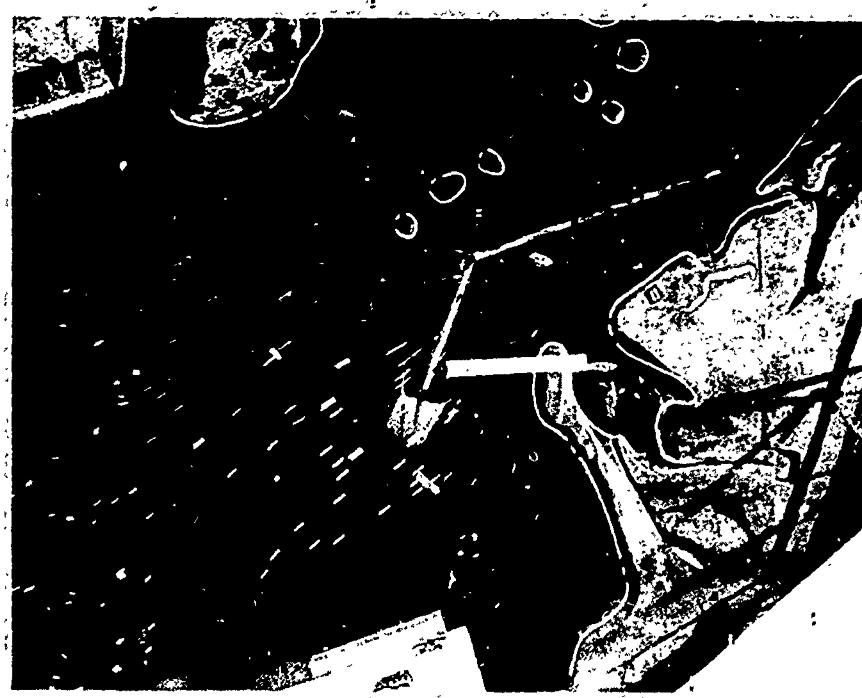
VELOCITY SCALE

5 0 5 10 15 FPS

PHOTO 44



HOUR 10



HOUR 11

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 3

HOURS 10 & 11, -4-FT X 75-FT CHANNEL

VELOCITY SCALE:

5 0 5 10 15 FPS

PHOTO 45.

HOUR 14

HOUR 15

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 4

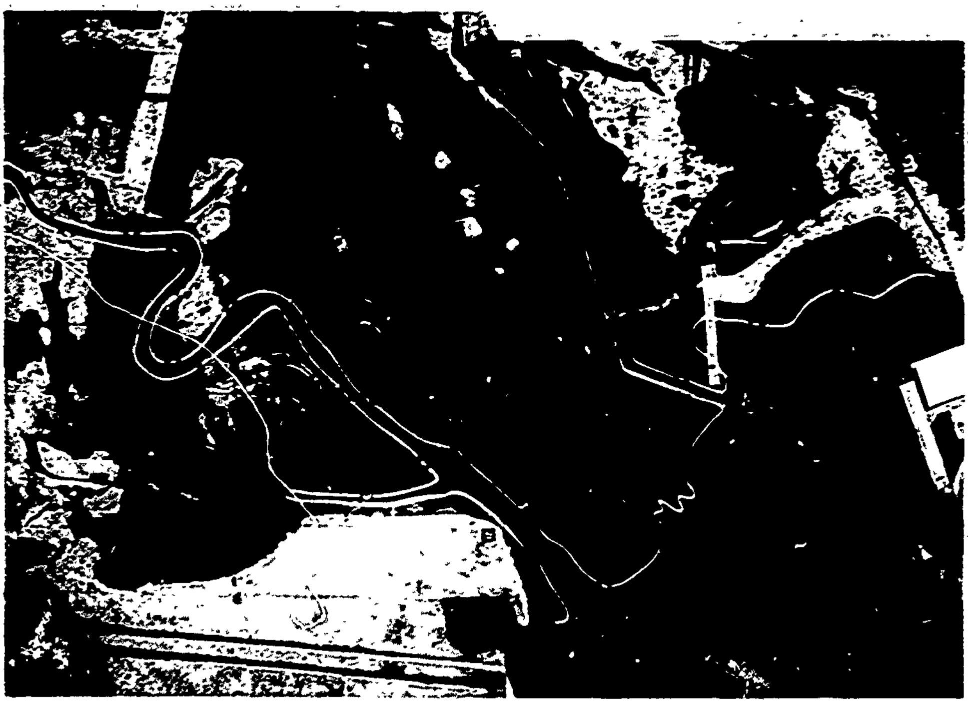
HOURS 14 & 15, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 46

HOUR 20



HOUR 21

MODEL TEST DATA

TIDE RANGE	[illegible] FT
DISCHARGE	
MENDENHALL	[illegible] CFS
LEMON CREEK	[illegible] CFS
SWITZER CREEK	75 CFS
FISH CREEK	[illegible] CFS

SURFACE CURRENT PATTERNS

PLAN 4

HOURS 20 & 21, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

0 [illegible] [illegible] 20 FPS

PHOTO 47

HOUR 4

HOUR 5

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 4

HOURS 4 & 5, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 48

HOUR 10

HOUR 11

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL	3000 CFS
LEMON CREEK	1050 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	400 CFS

SURFACE CURRENT PATTERNS

PLAN 4

HOURS 10 & 11, -4-FT X 75-FT CHANNEL

VELOCITY SCALE

PHOTO 49

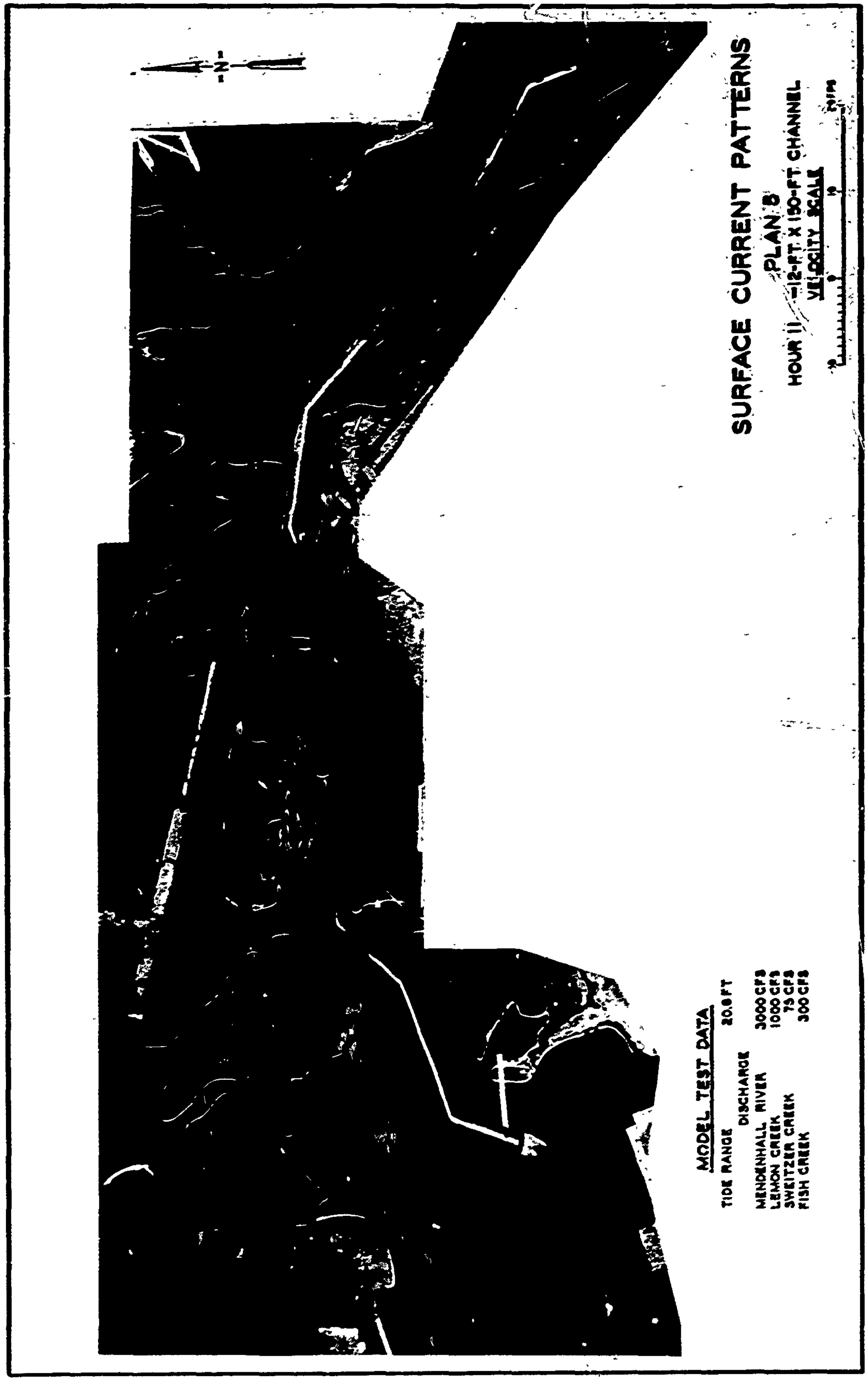

SURFACE CURRENT PATTERNS
PLAN 8
HOUR 11 — 12-FT X 150-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 50

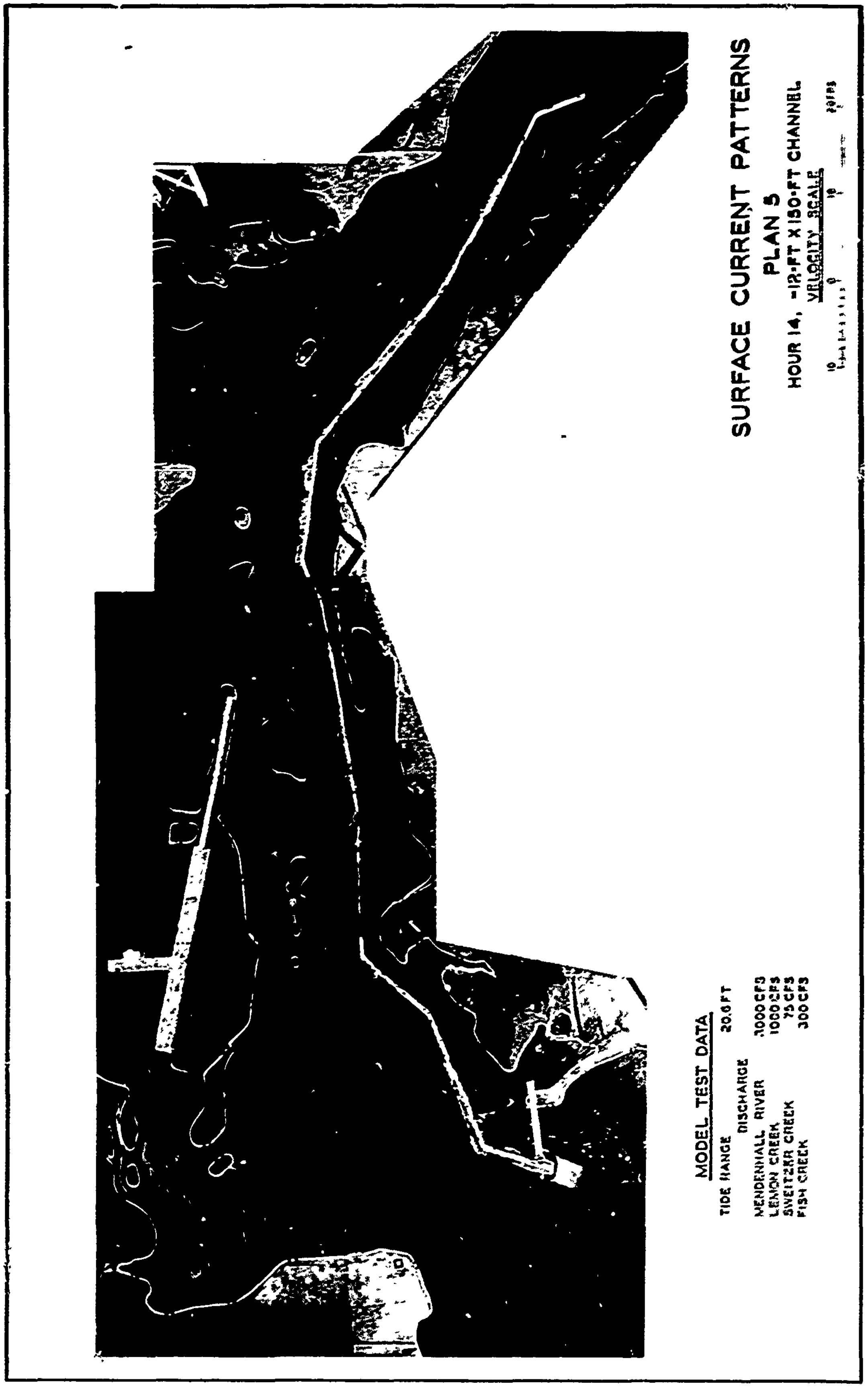
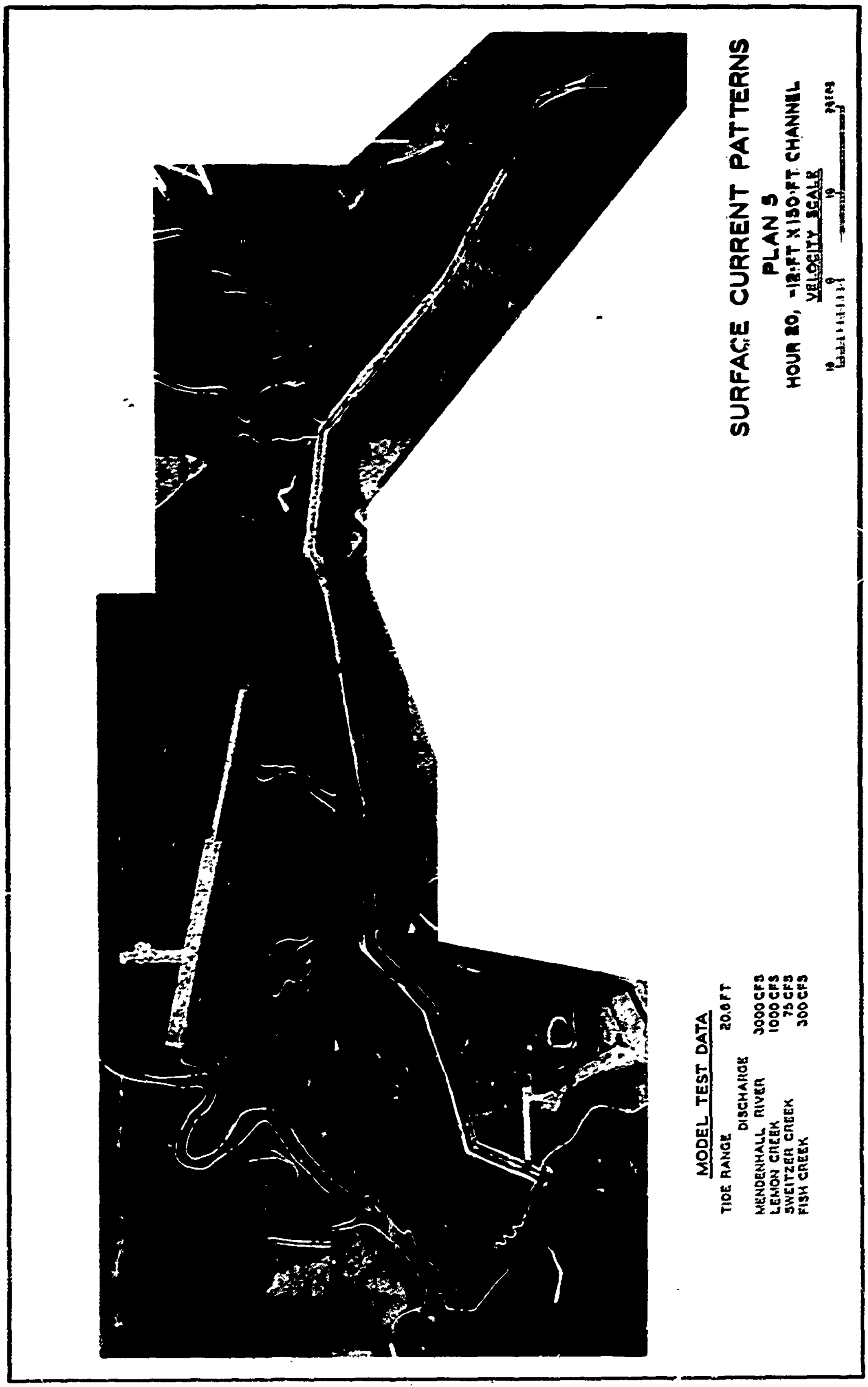

SURFACE CURRENT PATTERNS
PLAN 5
HOUR 14, -12-FT X 150-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 1000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 51



SURFACE CURRENT PATTERNS
PLAN 5
HOUR 20, -12-FT X 150-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 52

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 5

HOUR 4, -12-FT X 150-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

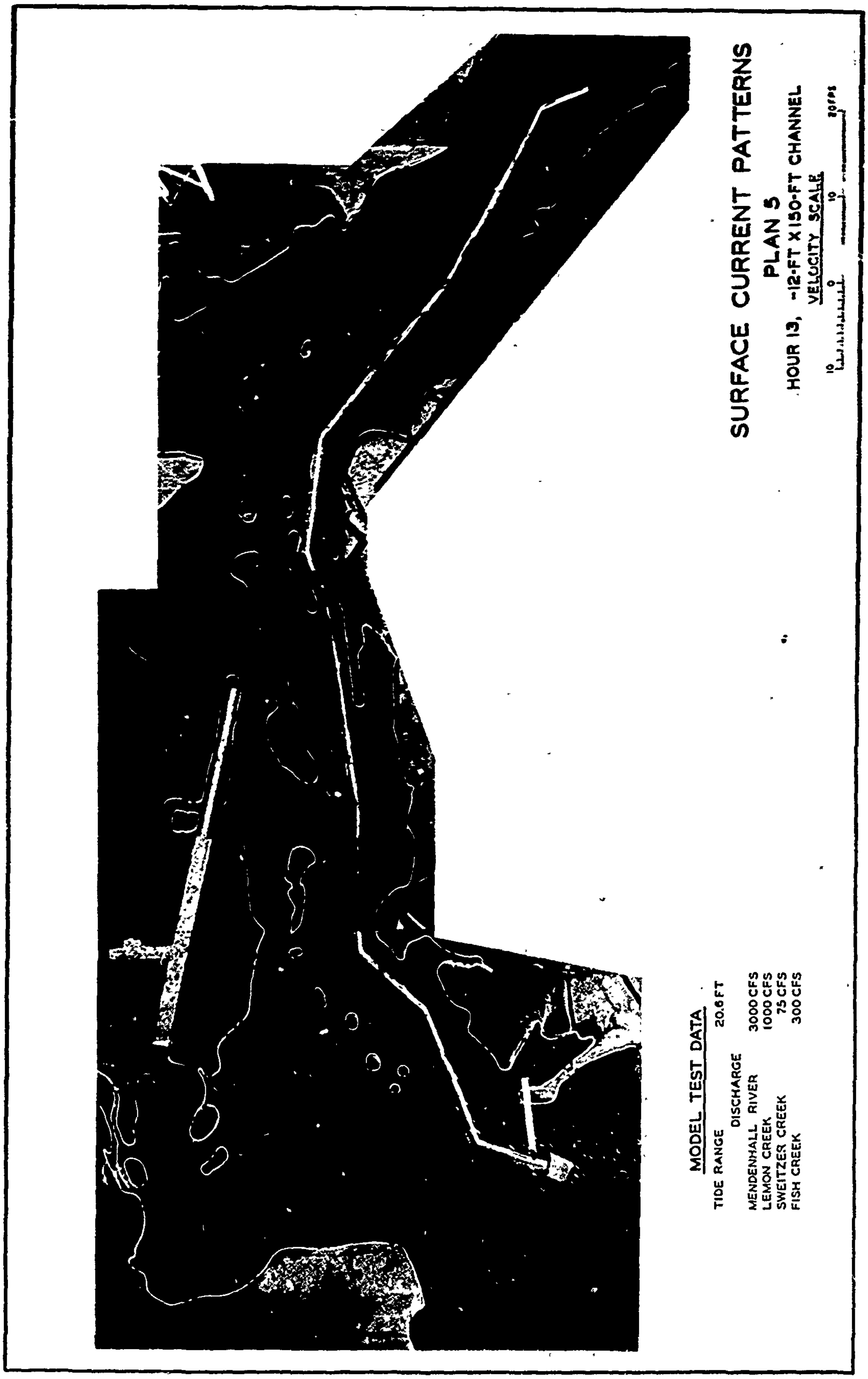

SURFACE CURRENT PATTERNS
PLAN 5
HOUR 13, -12-FT X 150-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 54

MODEL TEST DATA

TIDE RANGE		20.6 FT
	DISCHARGE	
MENDENHALL RIVER		3000 CFS
LEMON CREEK		1000 CFS
SWEITZER CREEK		75 CFS
FISH CREEK		300 CFS

SURFACE CURRENT PATTERNS
PLAN 6
HOUR 14, -12-FT. X 150-FT CHANNEL

VELOCITY SCALE
10 0 10 20FPS

PHOTO 55

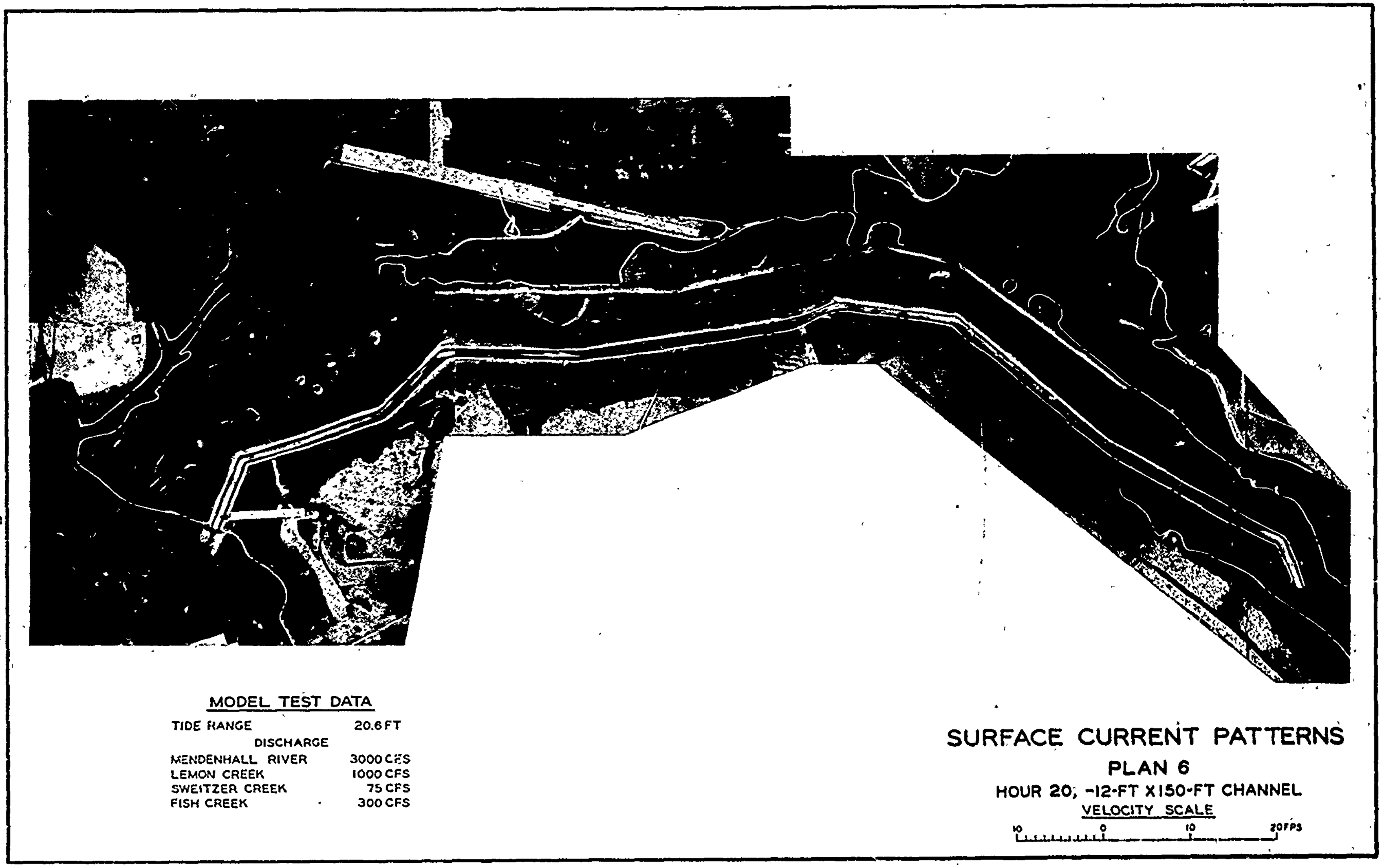

MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
PLAN 6
HOUR 20; -12-FT X 150-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 56

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS
PLAN 6
HOUR 4, -12-FT X 150-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS

PHOTO 57

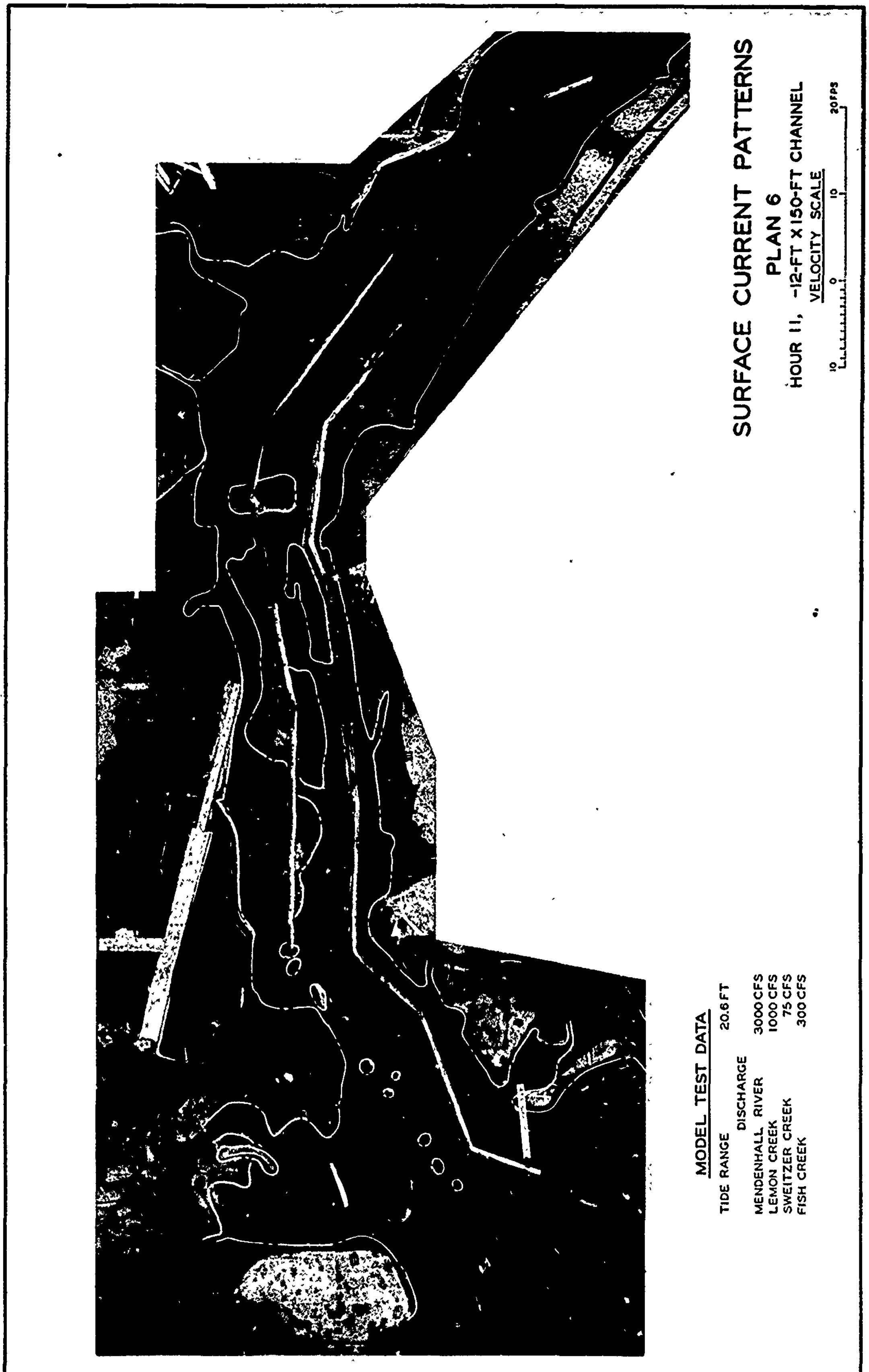
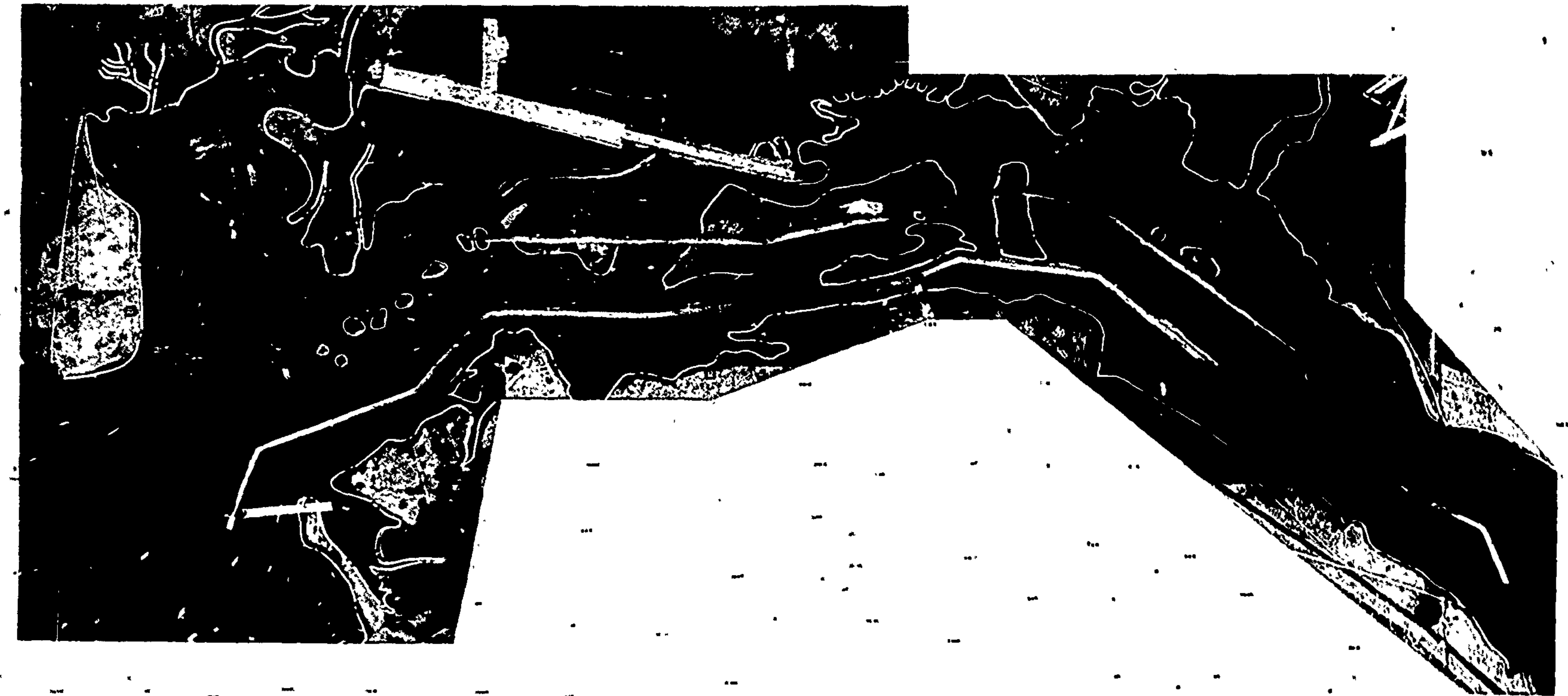

SURFACE CURRENT PATTERNS
PLAN 6
HOUR 11, -12-FT X 150-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 58



MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

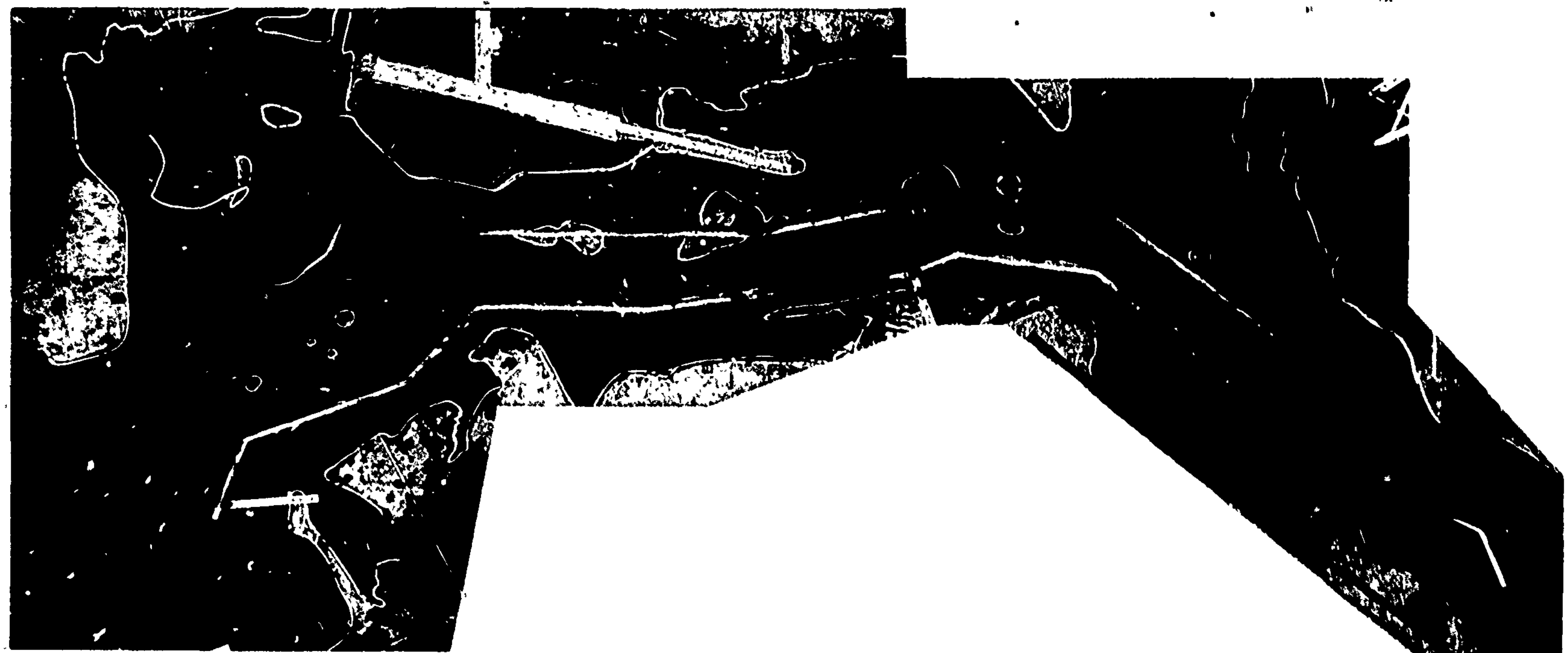
PLAN 6

HOUR 12, -12-FT X 150-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 59



MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

PLAN 6

HOUR 13, -12-FT X 150-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 60

MODEL TEST DATA

TIDE RANGE	20.6 FT
DISCHARGE	
MENDENHALL RIVER	3000 CFS
LEMON CREEK	1000 CFS
SWEITZER CREEK	75 CFS
FISH CREEK	300 CFS

SURFACE CURRENT PATTERNS

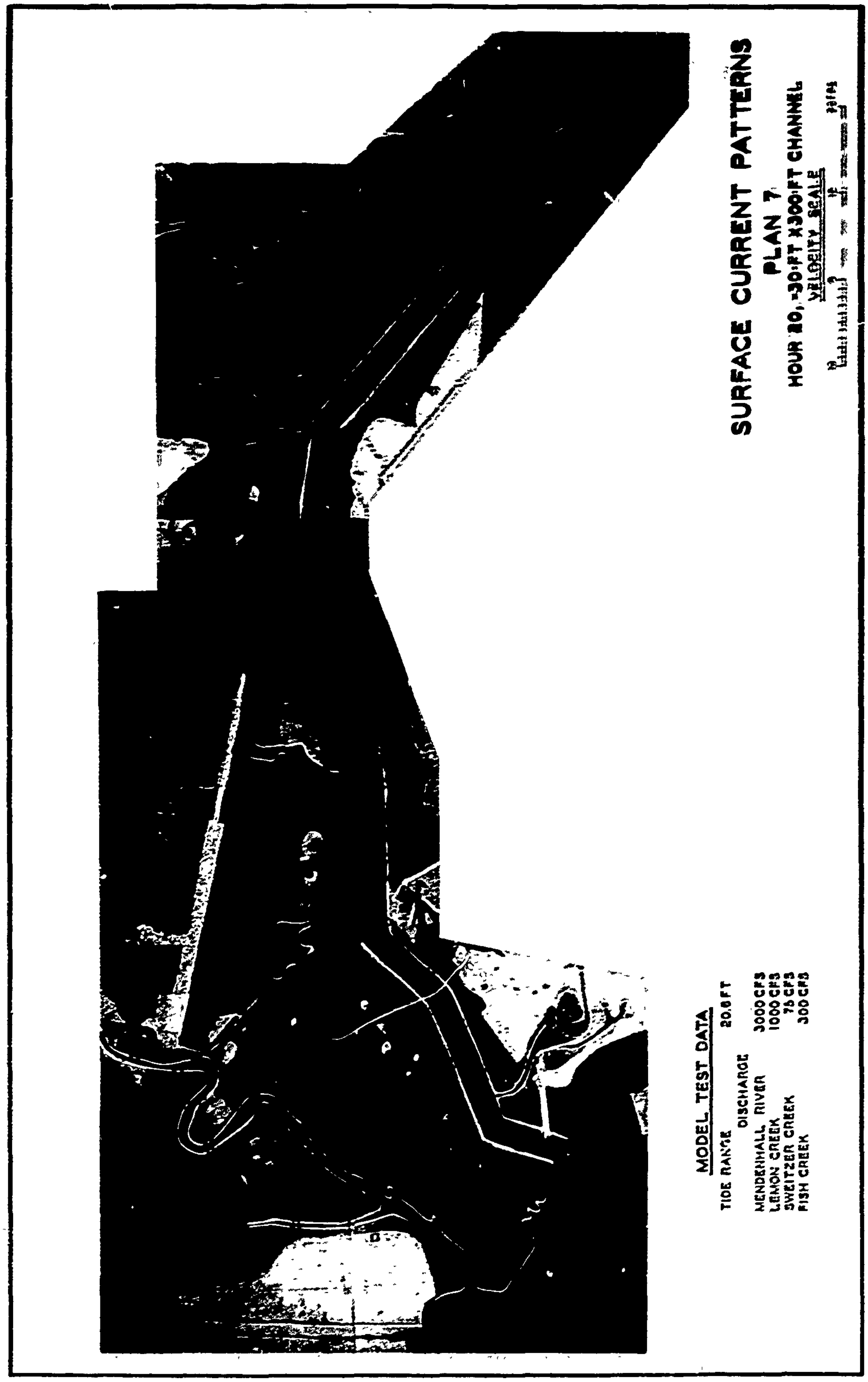
PLAN 7

HOUR 14, -30-FT X 300-FT CHANNEL

VELOCITY SCALE

10 0 10 20 FPS

PHOTO 61



SURFACE CURRENT PATTERNS
PLAN 7
HOUR 20, -30-FT X 300-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.0 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 62

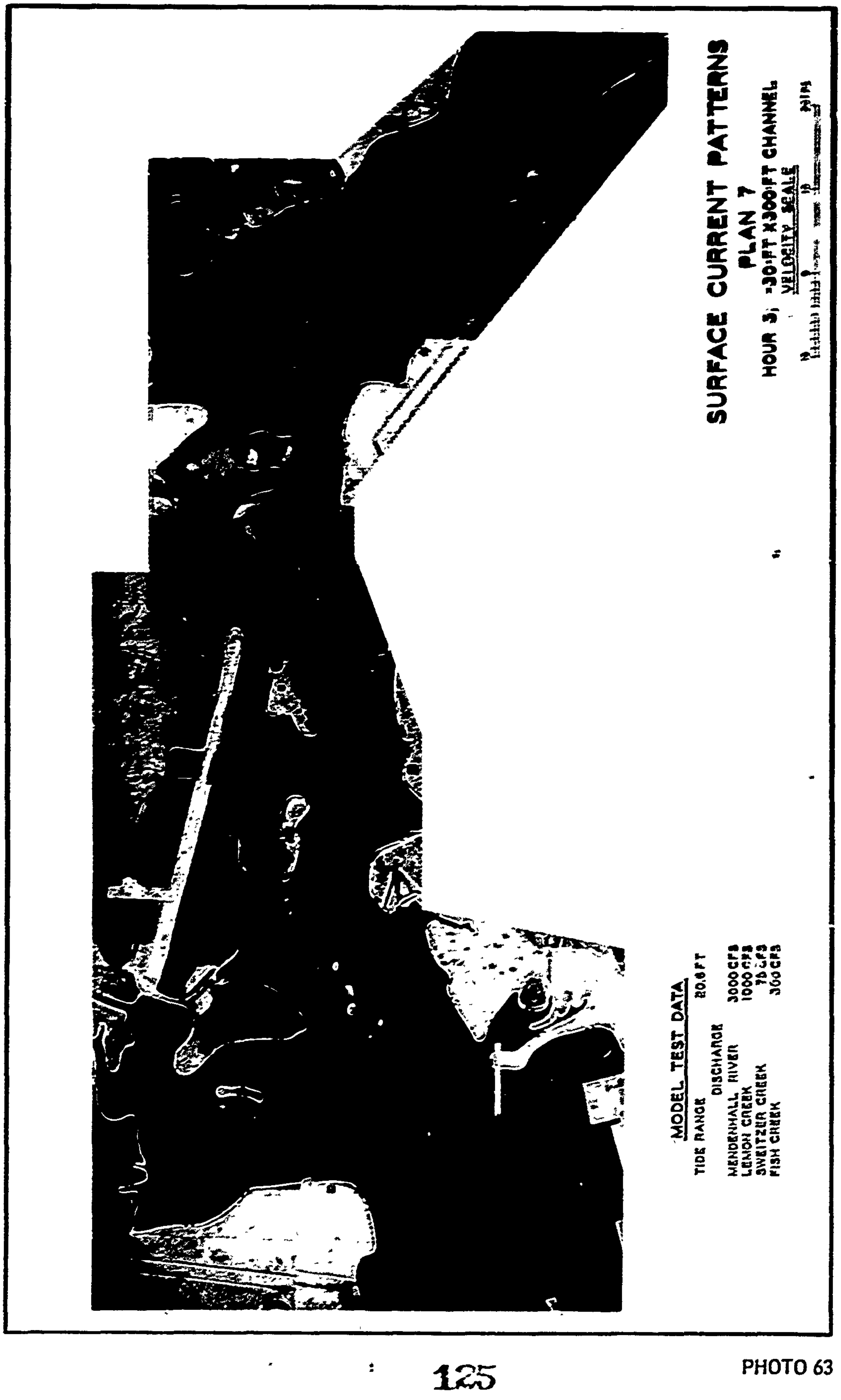

MODEL TEST DATA
TIDE RANGE
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS
SURFACE CURRENT PATTERNS
PLAN 7
HOUR 3, -30-FT X 300-FT CHANNEL
VELOCITY SCALE

PHOTO 63

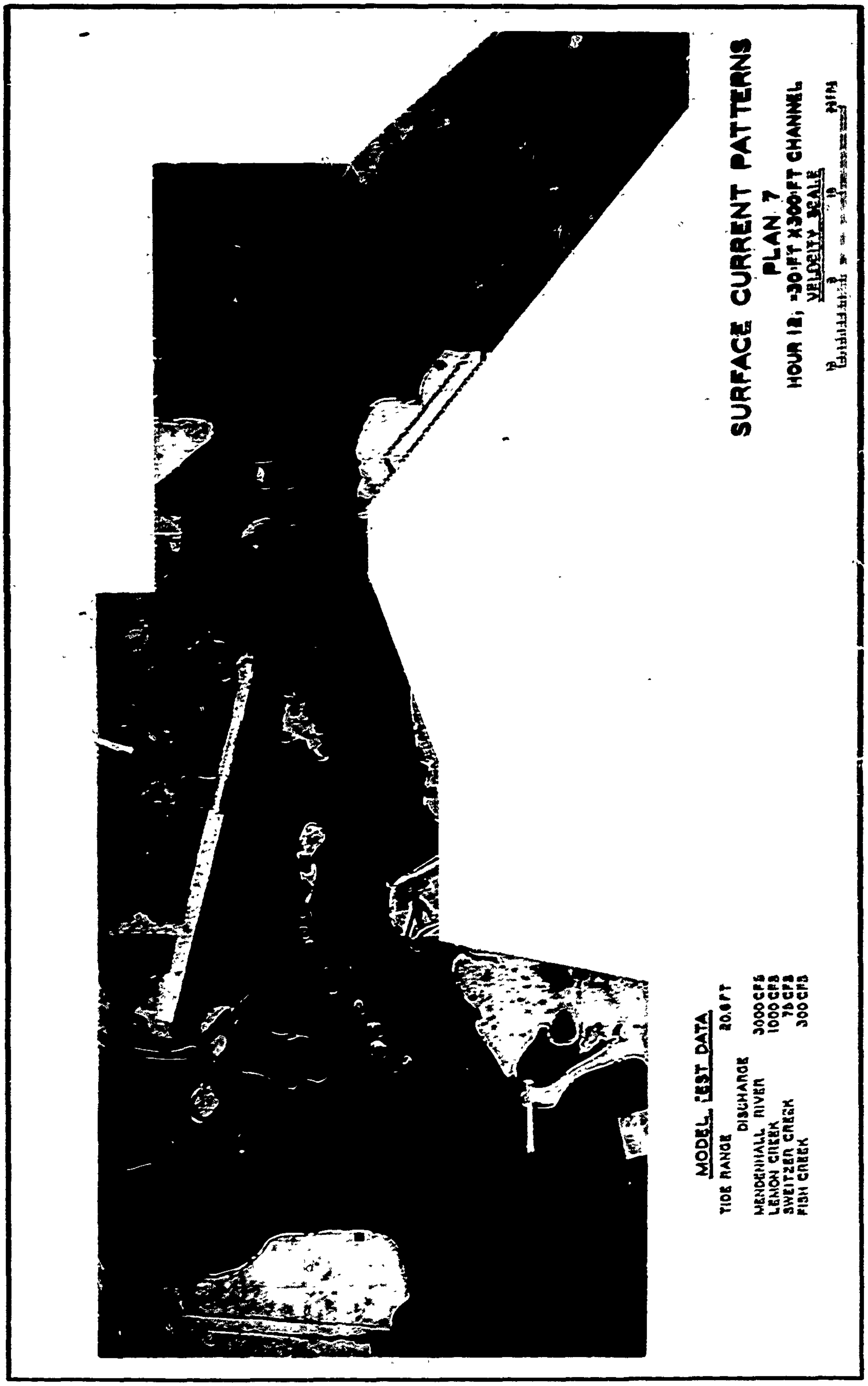

SURFACE CURRENT PATTERNS
PLAN 7
HOUR 12, -30-FT X 300-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 64

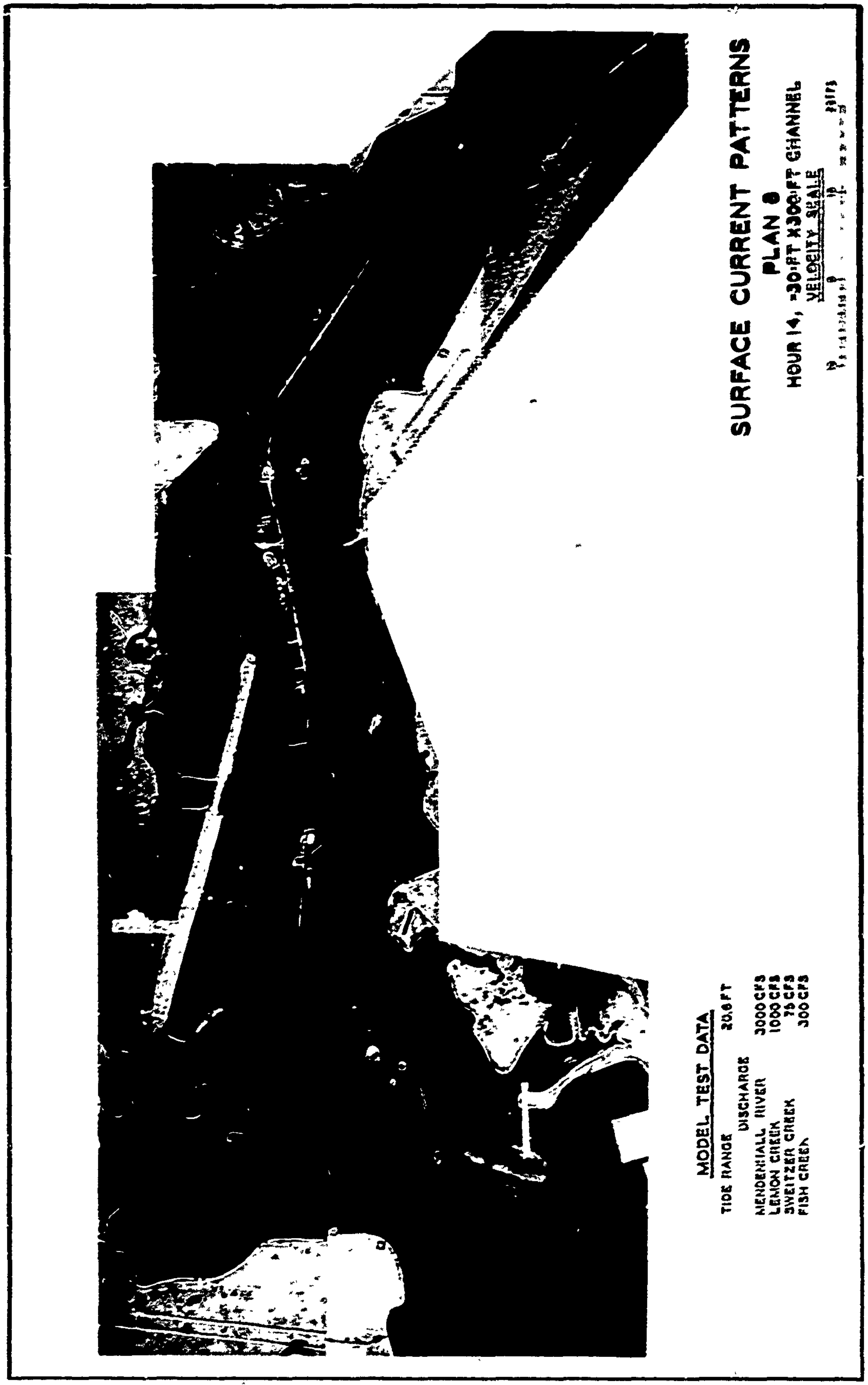
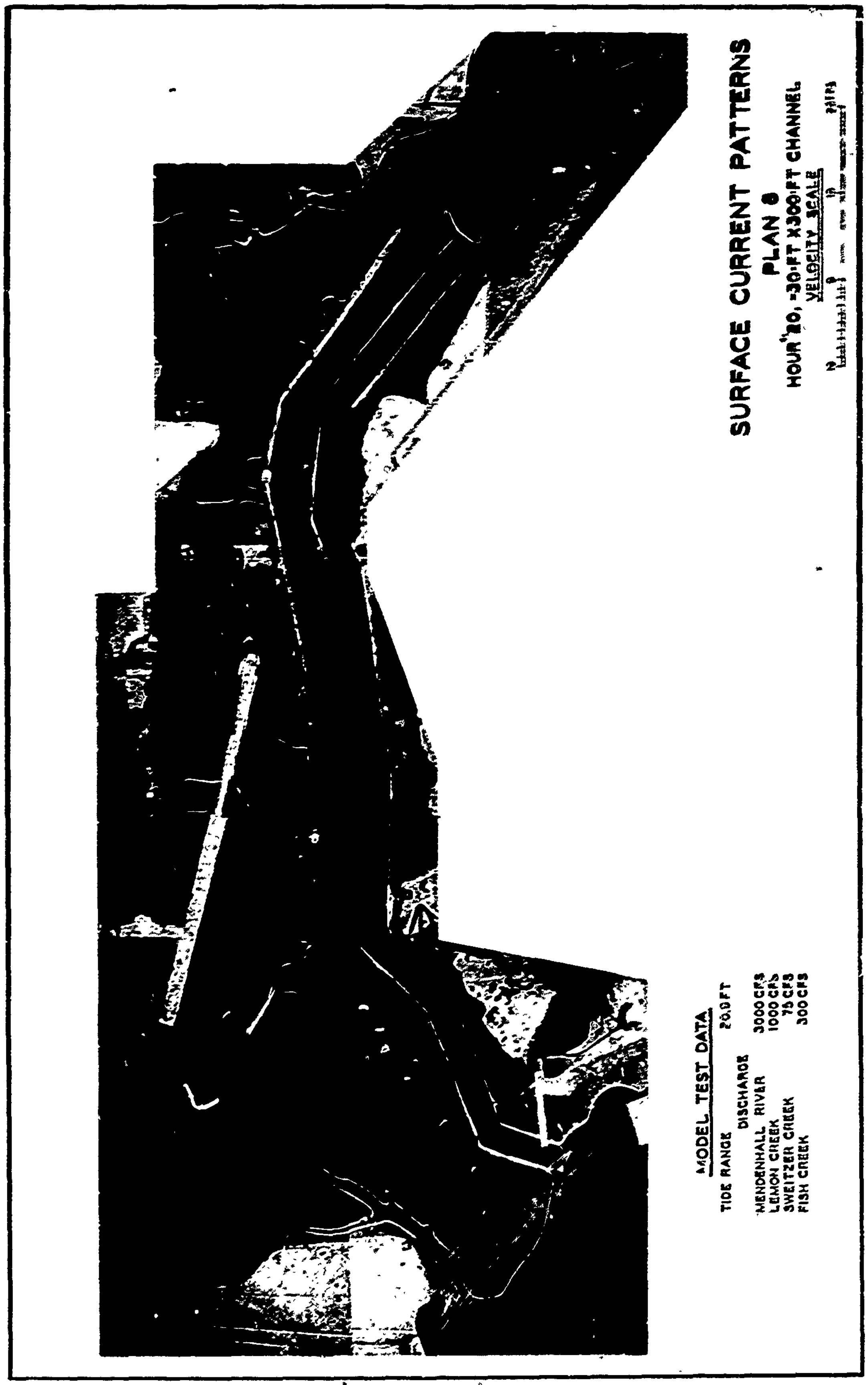

SURFACE CURRENT PATTERNS
PLAN 8
HOUR 14, 30-FT X 300-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 65



SURFACE CURRENT PATTERNS
PLAN 8
HOUR 20, -30-FT X300-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.0 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 66

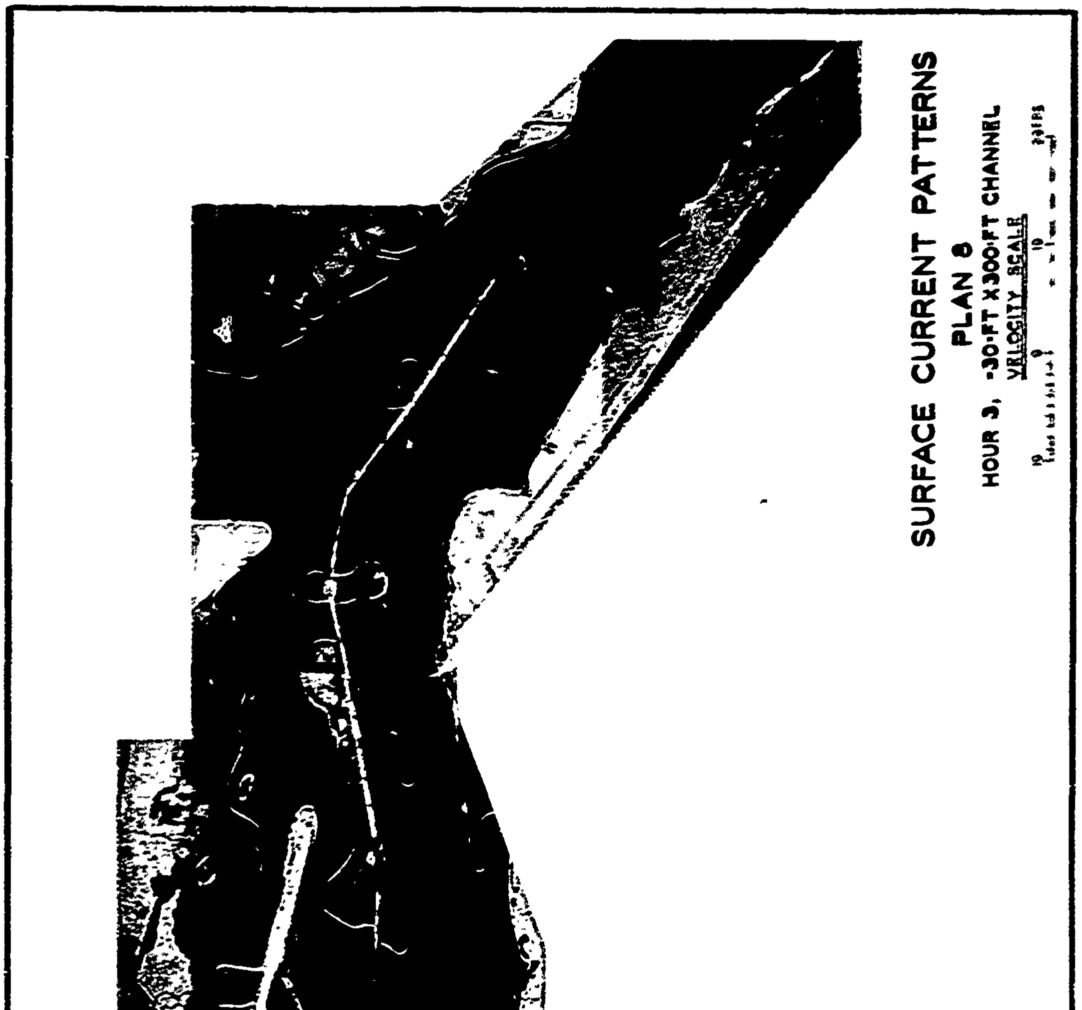

SURFACE CURRENT PATTERNS
PLAN 8
HOUR 3, -30-FT X 300-FT CHANNEL
VELOCITY SCALE
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 67

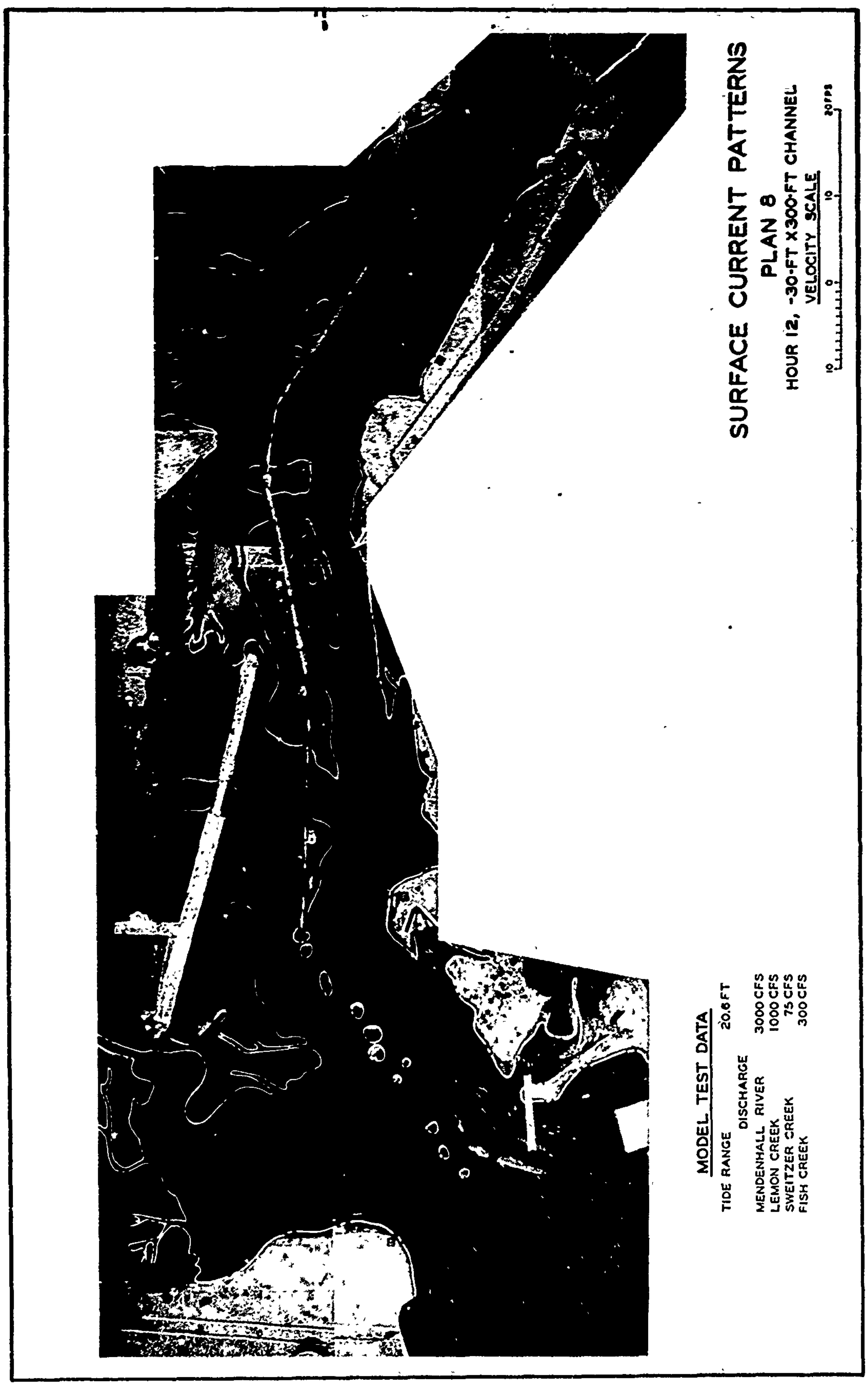
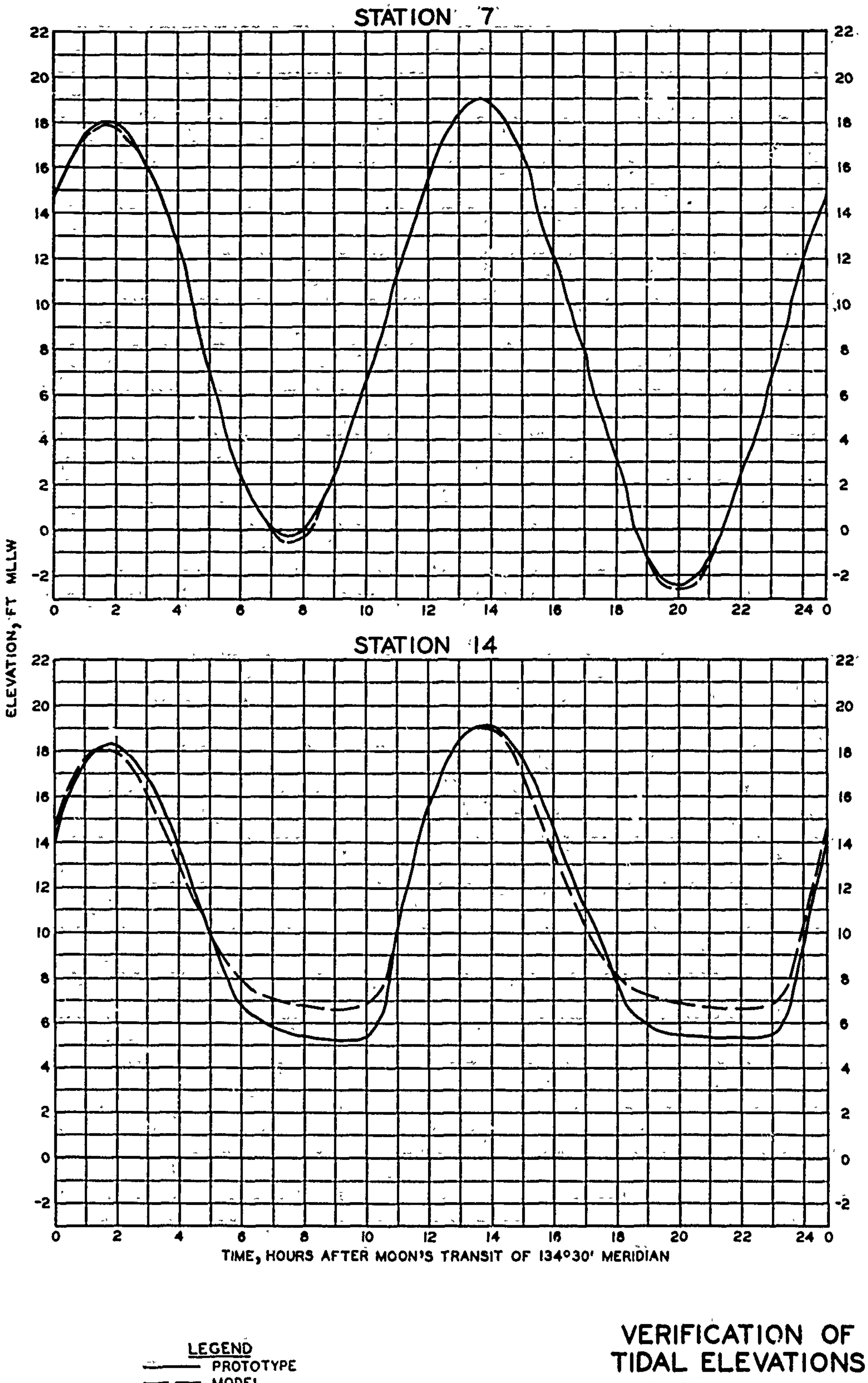
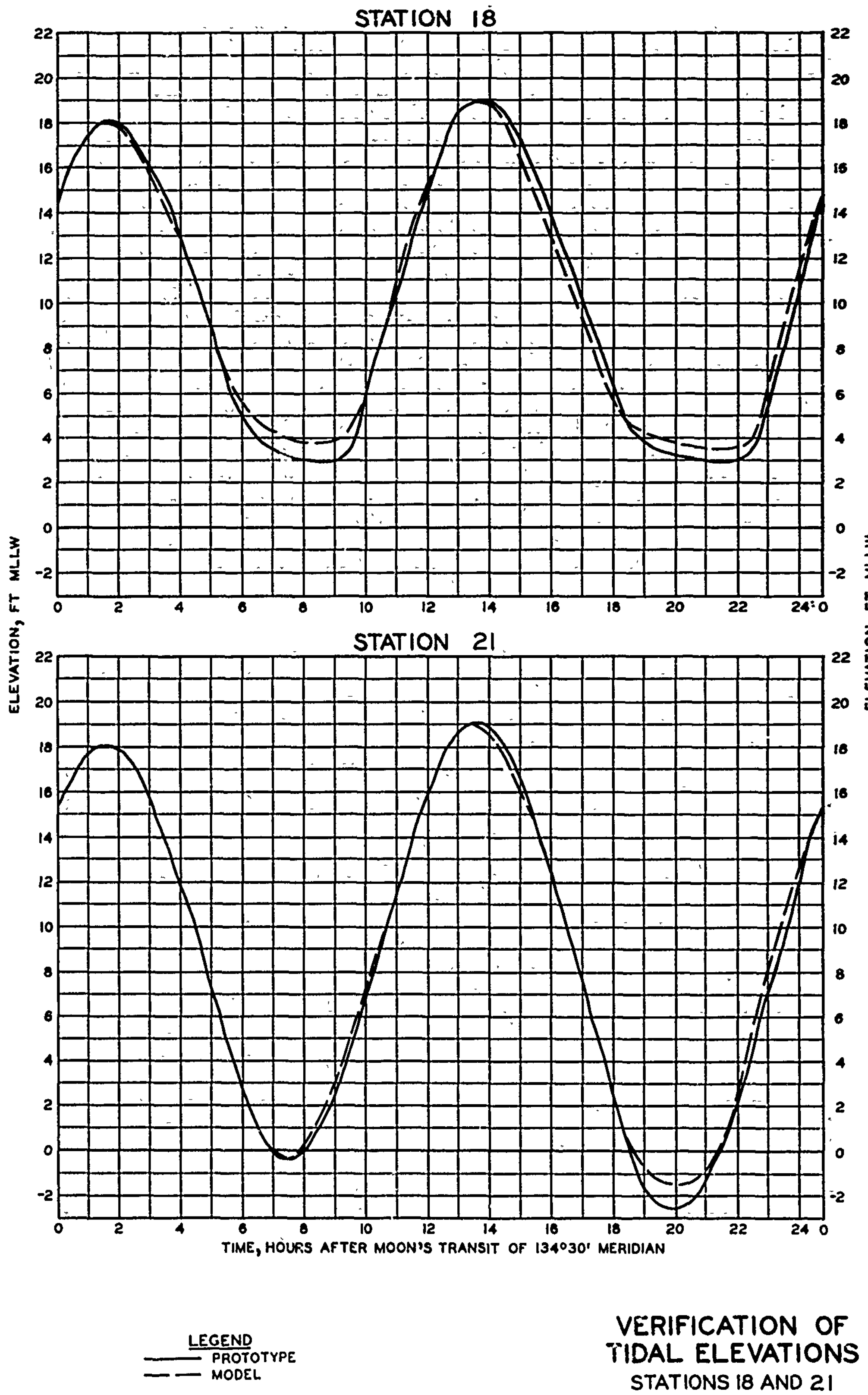

SURFACE CURRENT PATTERNS
PLAN 8
HOUR 12, -30-FT X 300-FT CHANNEL
VELOCITY SCALE
10 0 10 20 FPS
MODEL TEST DATA
TIDE RANGE 20.6 FT
DISCHARGE
MENDENHALL RIVER 3000 CFS
LEMON CREEK 1000 CFS
SWEITZER CREEK 75 CFS
FISH CREEK 300 CFS

PHOTO 68

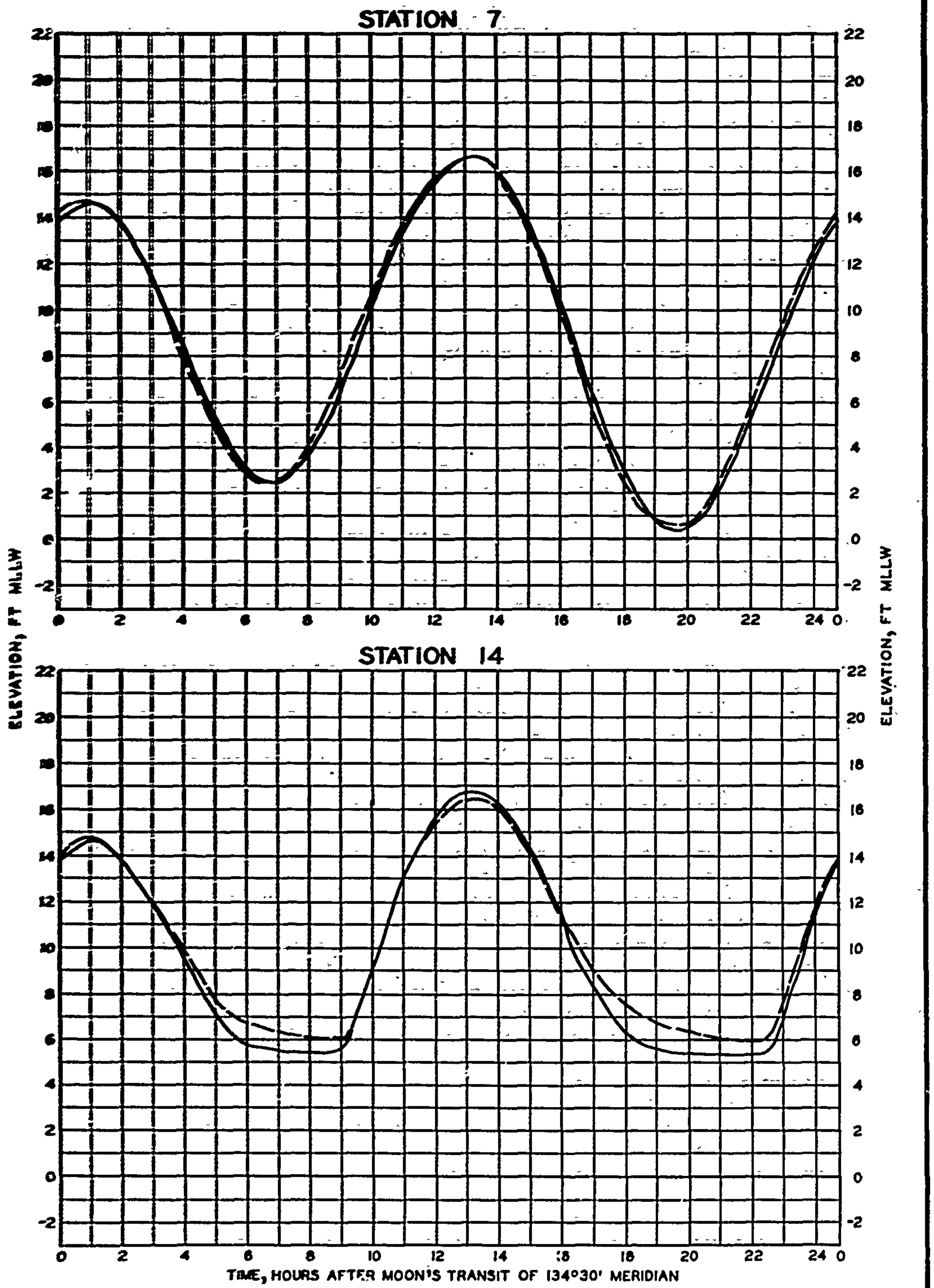


VERIFICATION OF
TIDAL ELEVATIONS
STATIONS 7 AND 14
SPRING TIDE

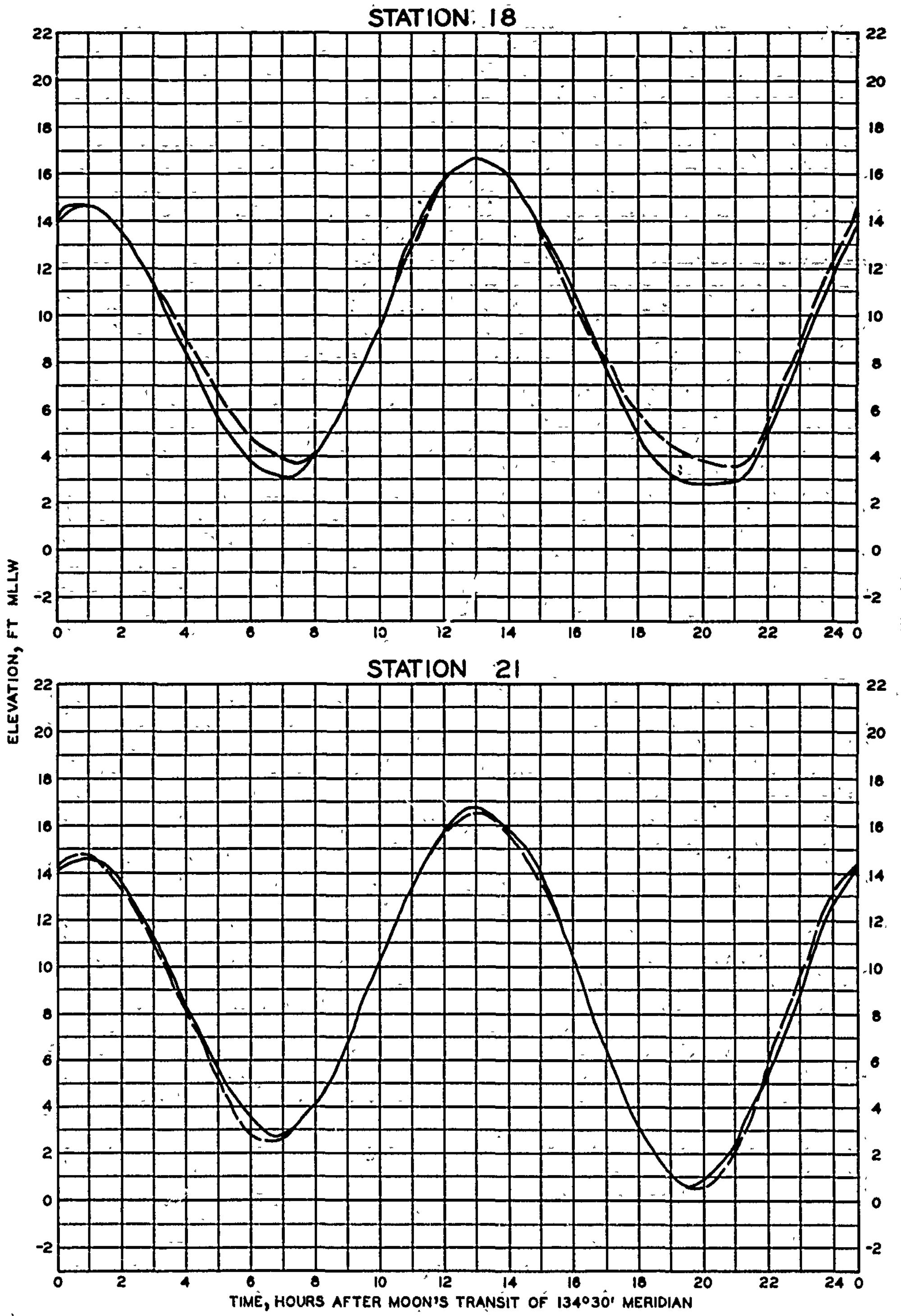


VERIFICATION OF
TIDAL ELEVATIONS
STATIONS 18 AND 21
SPRING TIDE

PLATE 2



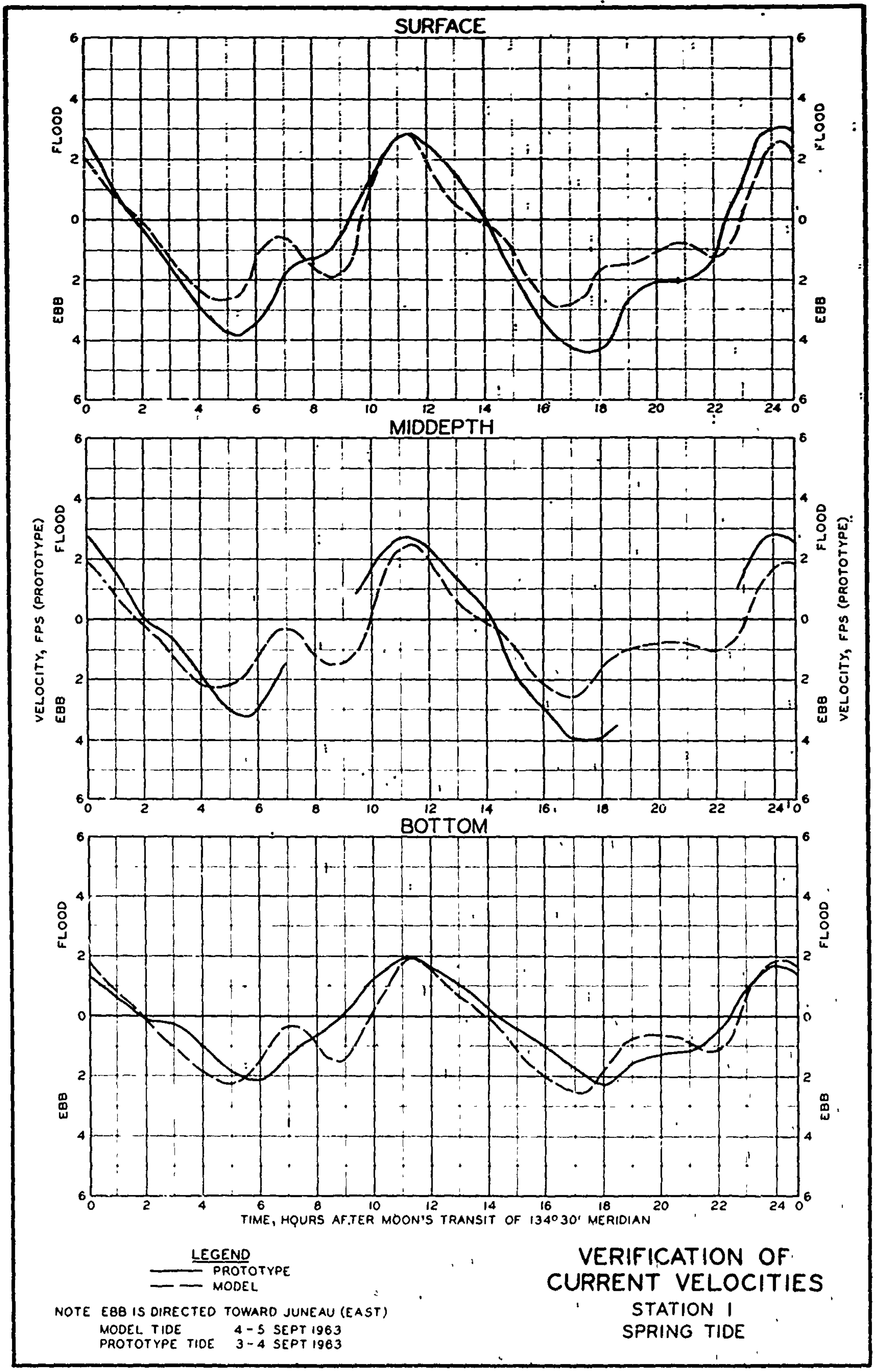
VERIFICATION OF TIDAL ELEVATIONS
STATIONS 7 AND 14
MEAN TIDE



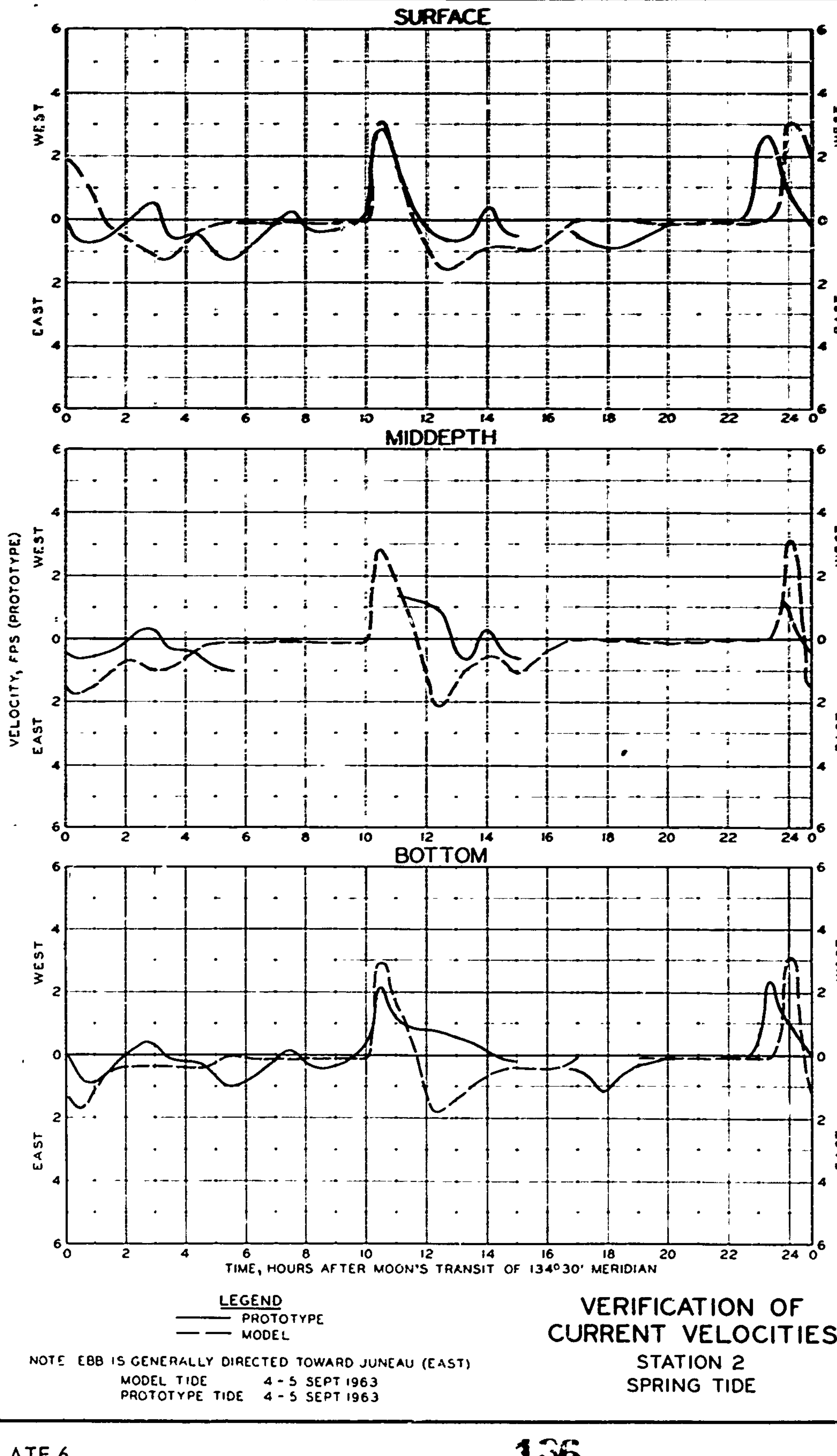
LEGEND
— — PROTOTYPE
—— — MODEL

VERIFICATION OF TIDAL ELEVATIONS
STATIONS 18 AND 21
MEAN TIDE

PLATE 4

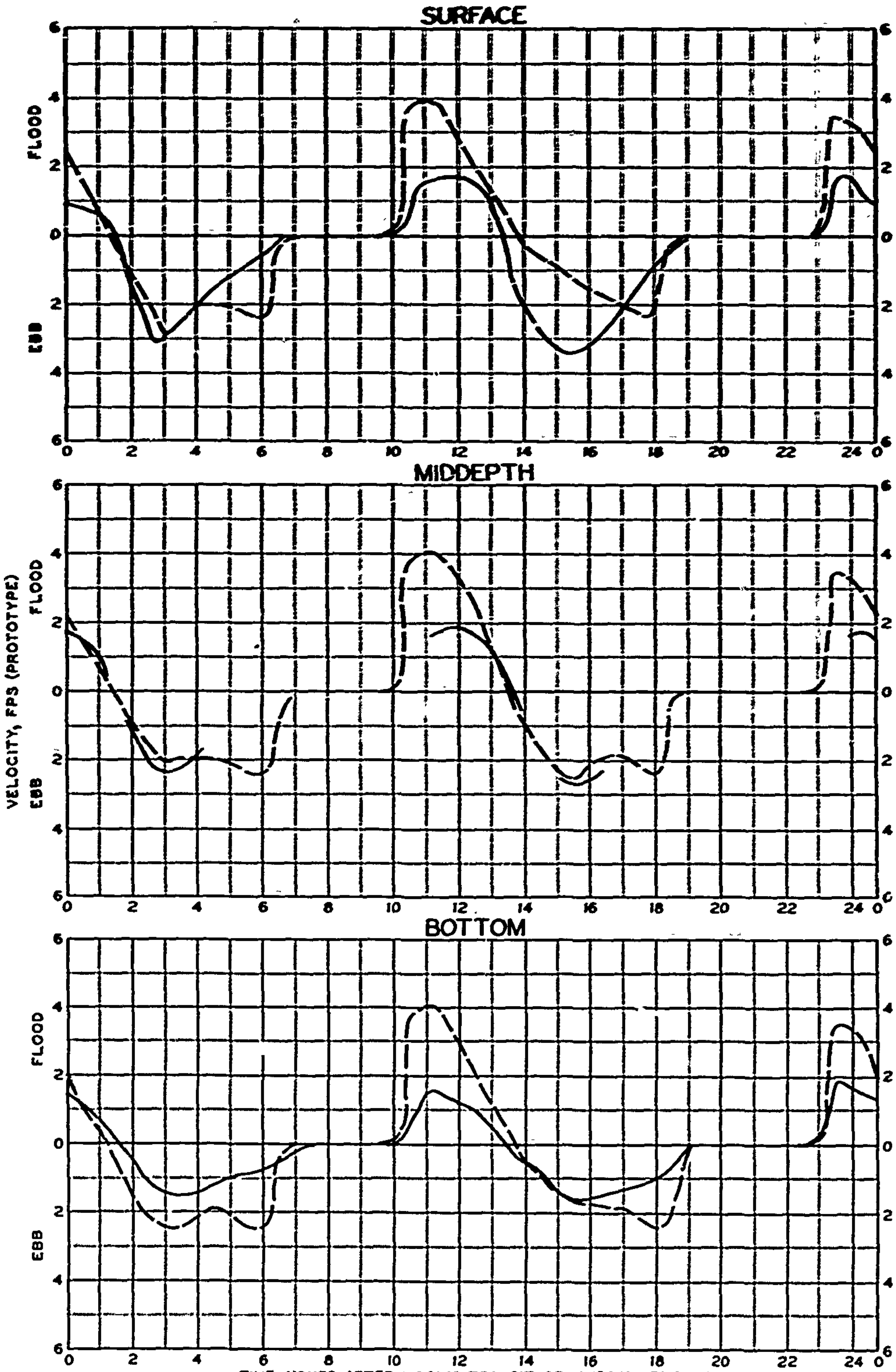


VERIFICATION OF CURRENT VELOCITIES
STATION 1
SPRING TIDE



VERIFICATION OF CURRENT VELOCITIES
STATION 2
SPRING TIDE

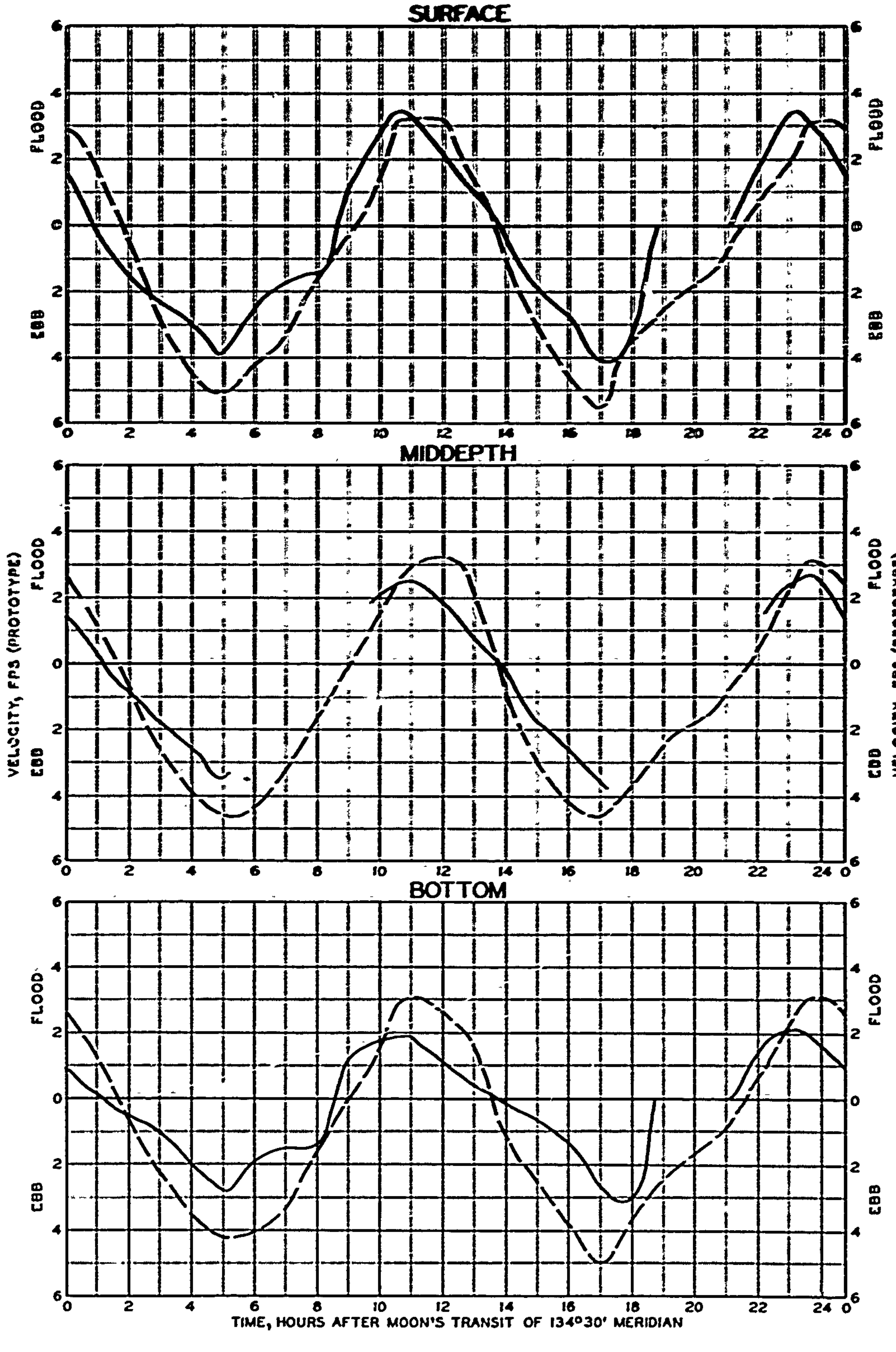
PLATE 6



LEGEND
—— PROTOTYPE
— — MODEL

NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)
MODEL TIDE.........4-5 SEPT 1963
PROTOTYPE TIDE...5-6 SEPT 1963

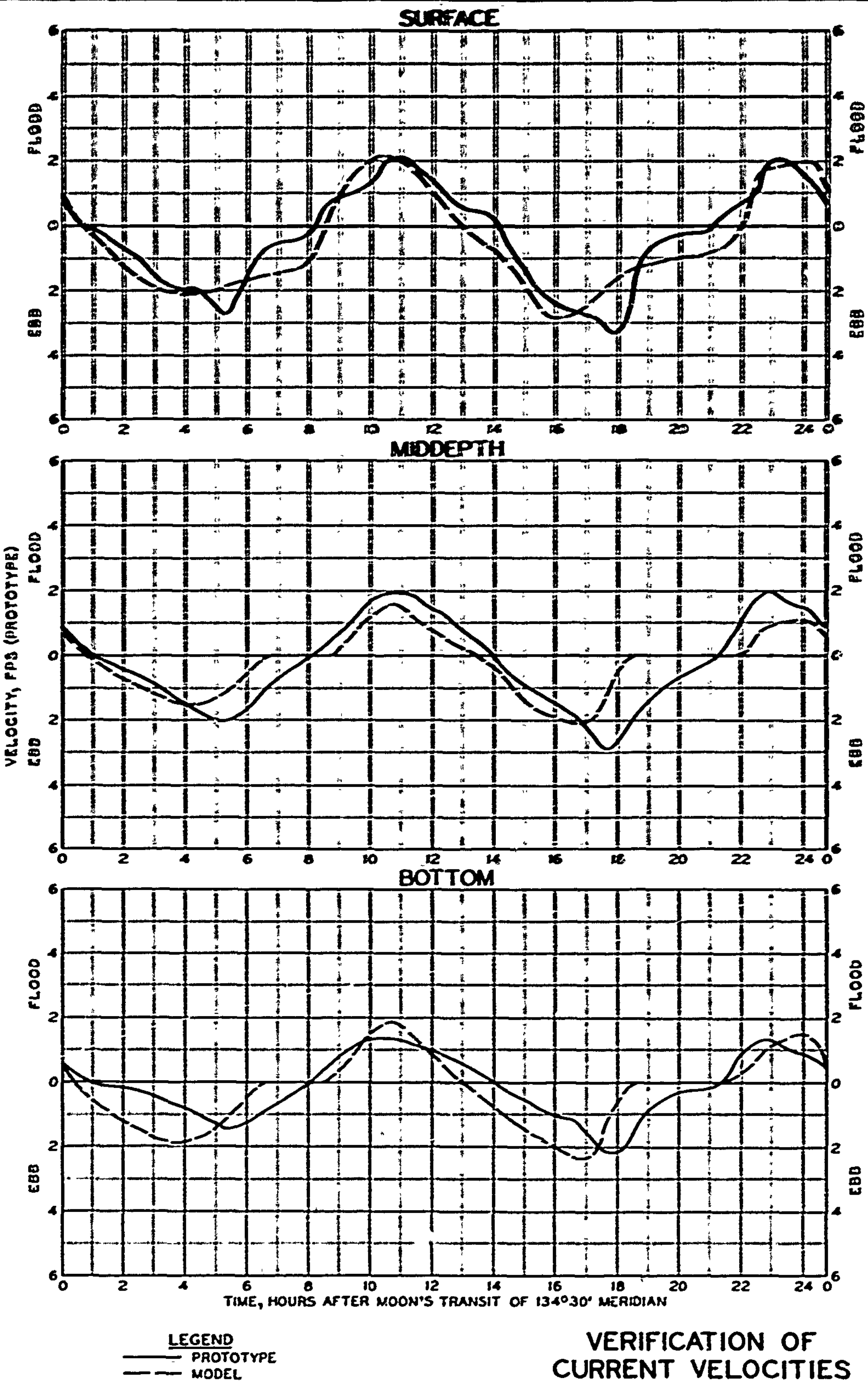
VERIFICATION OF CURRENT VELOCITIES
STATION 3
SPRING TIDE



NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)
MODEL TIDE.........4-5 SEPT 1963
PROTOTYPE TIDE...6-7 SEPT 1963

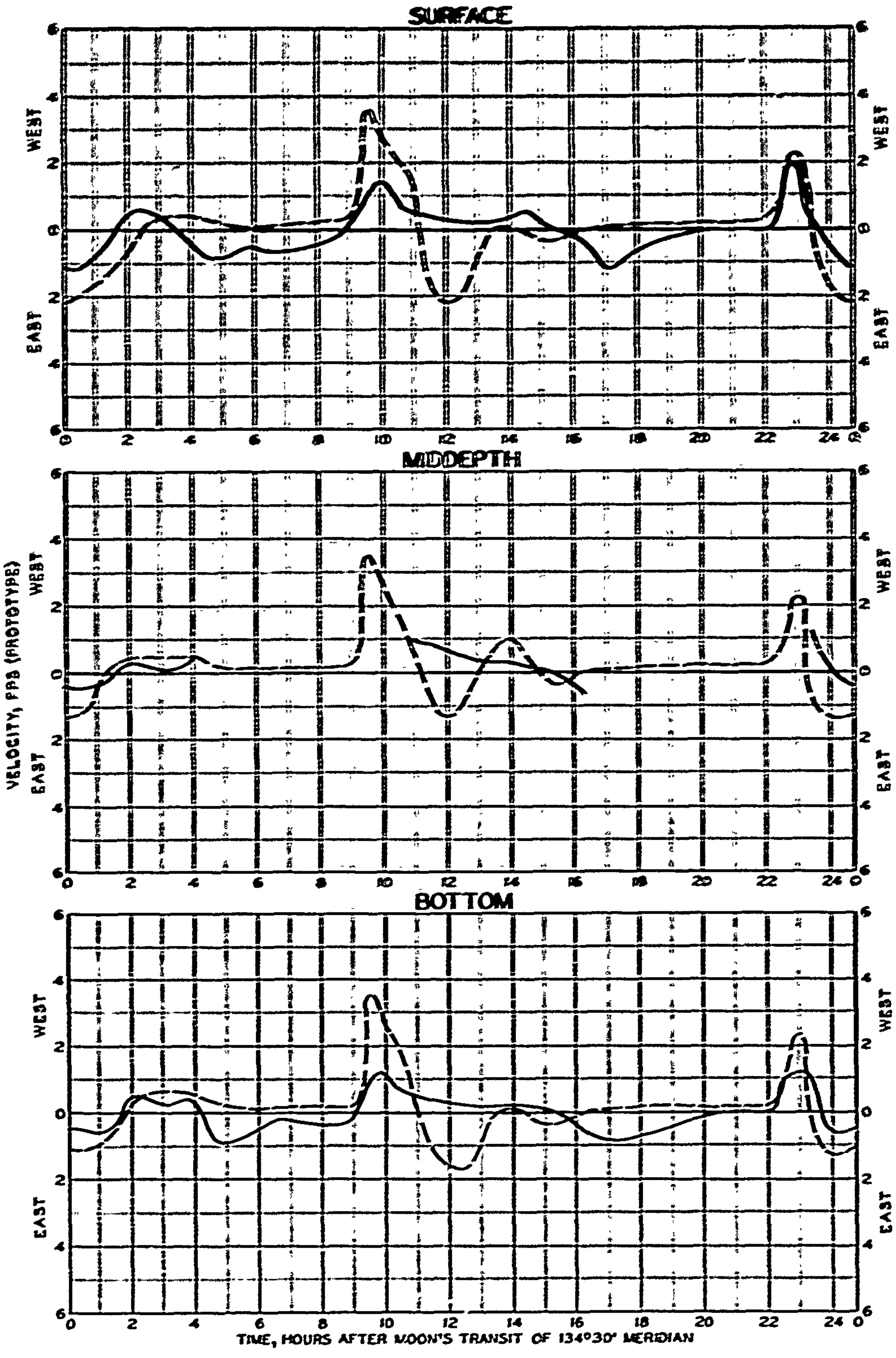
VERIFICATION OF CURRENT VELOCITIES
STATION 4
SPRING TIDE

PLATE 8



NOTE: EBB IS DIRECTED TOWARD JUNEAU (EAST)
MODEL TIDE........9-10 SEPT 1963
PROTOTYPE TIDE ..7-8 SEPT 1963

VERIFICATION OF CURRENT VELOCITIES
STATION 1
MEAN TIDE

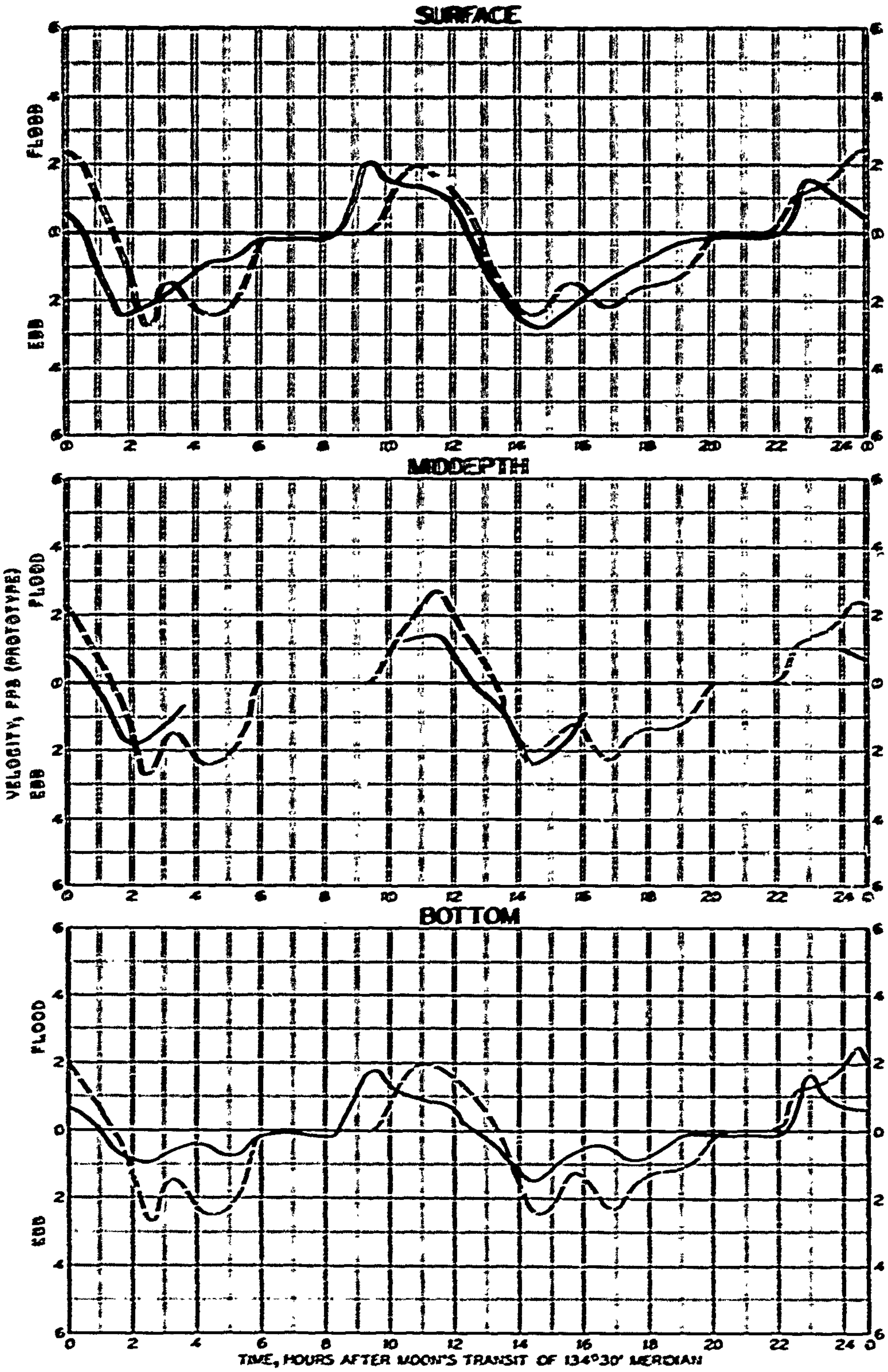


LEGEND
——— PROTOTYPE
— — MODEL

NOTE: EBB IS GENERALLY DIRECTED TOWARD JUNEAU (EAST)
MODEL TIDE... 9-10 SEPT 1963
PROTOTYPE TIDE...8-9 SEPT 1963

VERIFICATION OF
CURRENT VELOCITIES
STATION 2
MEAN TIDE

PLATE 10

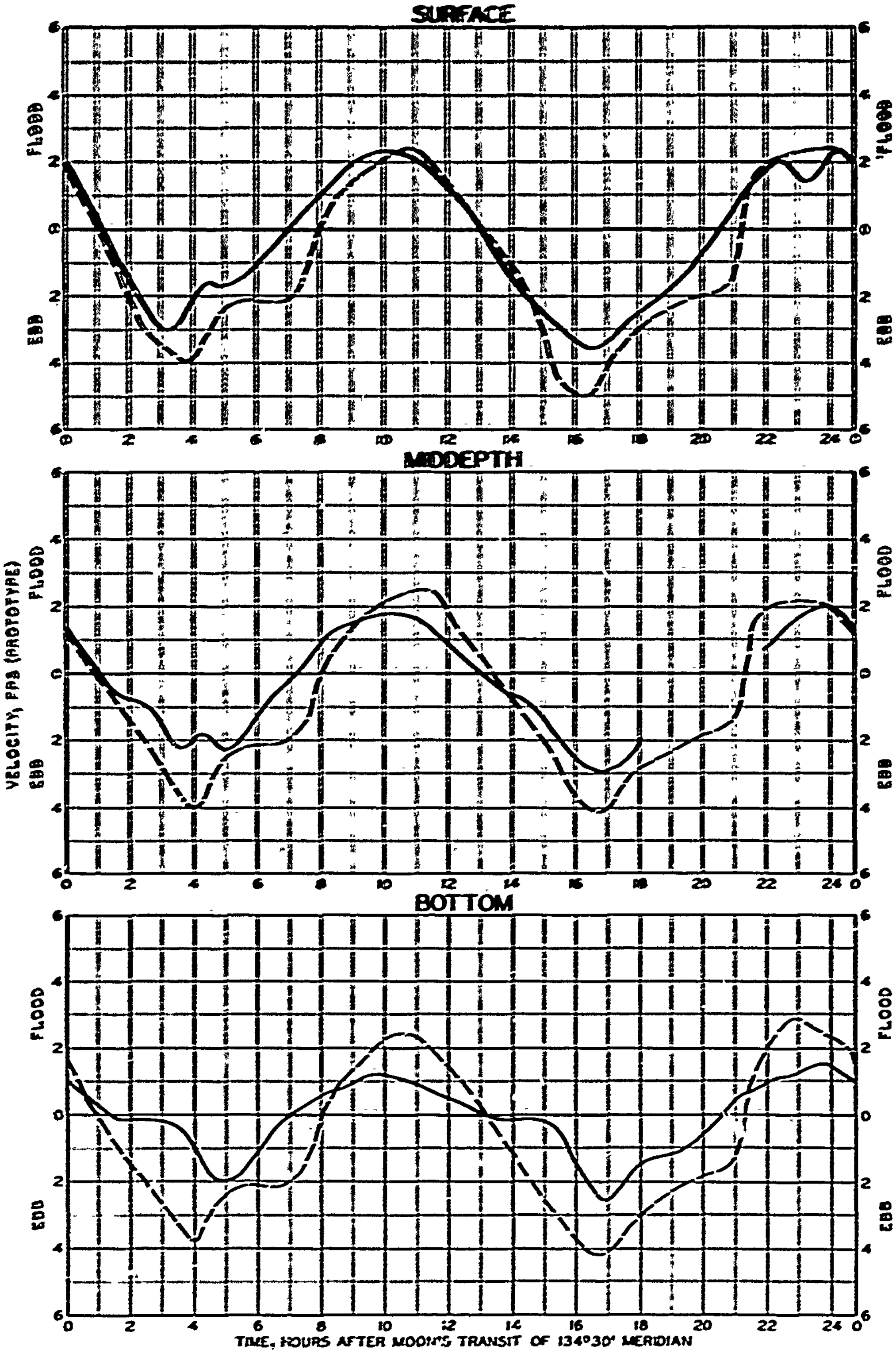


LEGEND
——— PROTOTYPE
— — — MODEL

NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)
MODEL TIDE........9-10 SEPT 1963
PROTOTYPE TIDE .9-10 SEPT 1963

VERIFICATION OF CURRENT VELOCITIES
STATION 3
MEAN TIDE

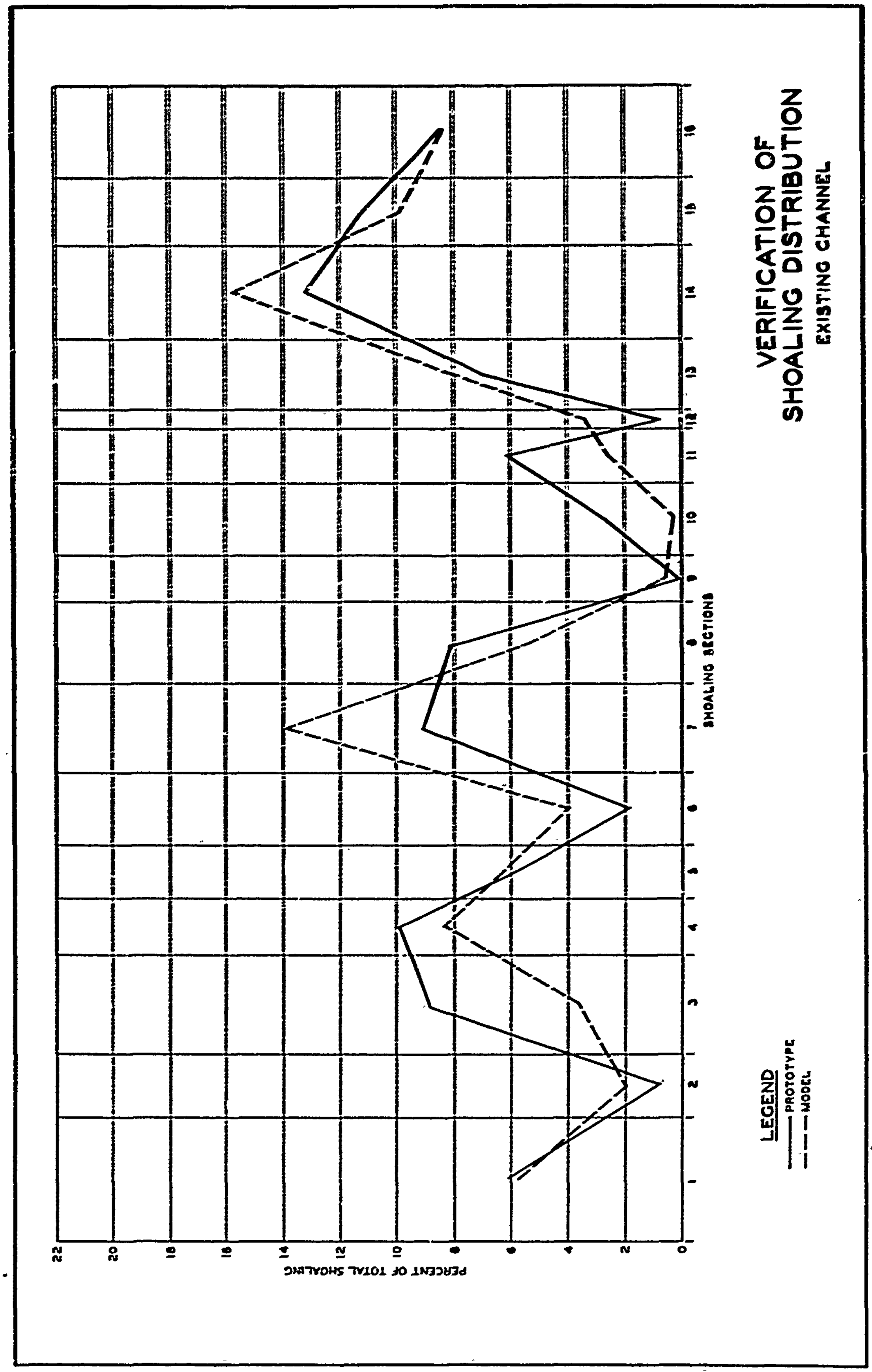
PLATE 11



LEGEND
—— PROTOTYPE
– – MODEL

NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)
MODEL TIDE.........9-10 SEPT 1963
PROTOTYPE TIDE....10-11 SEPT 1963

VERIFICATION OF CURRENT VELOCITIES
STATION 4
MEAN TIDE



VERIFICATION OF SHOALING DISTRIBUTION
EXISTING CHANNEL

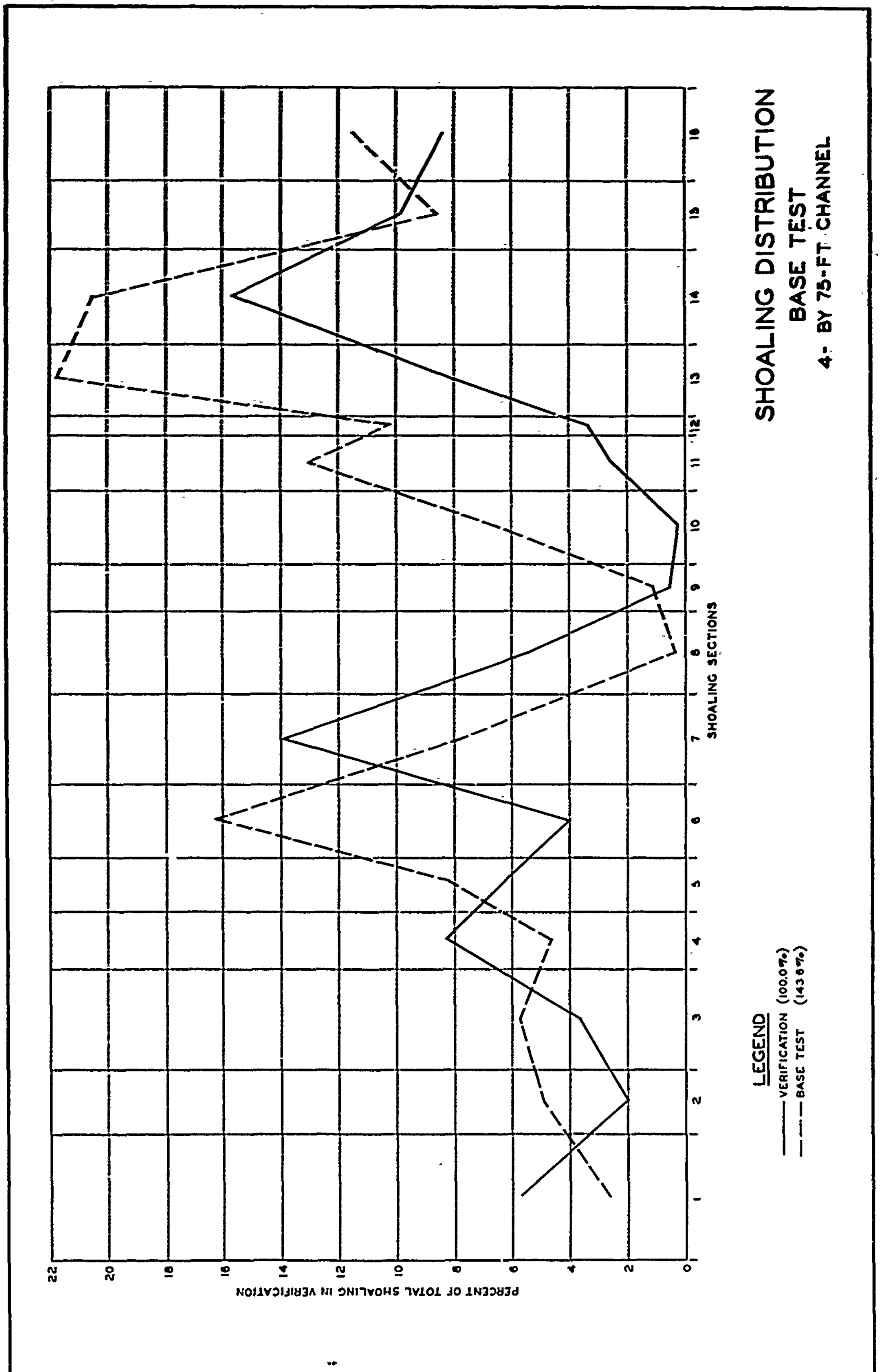
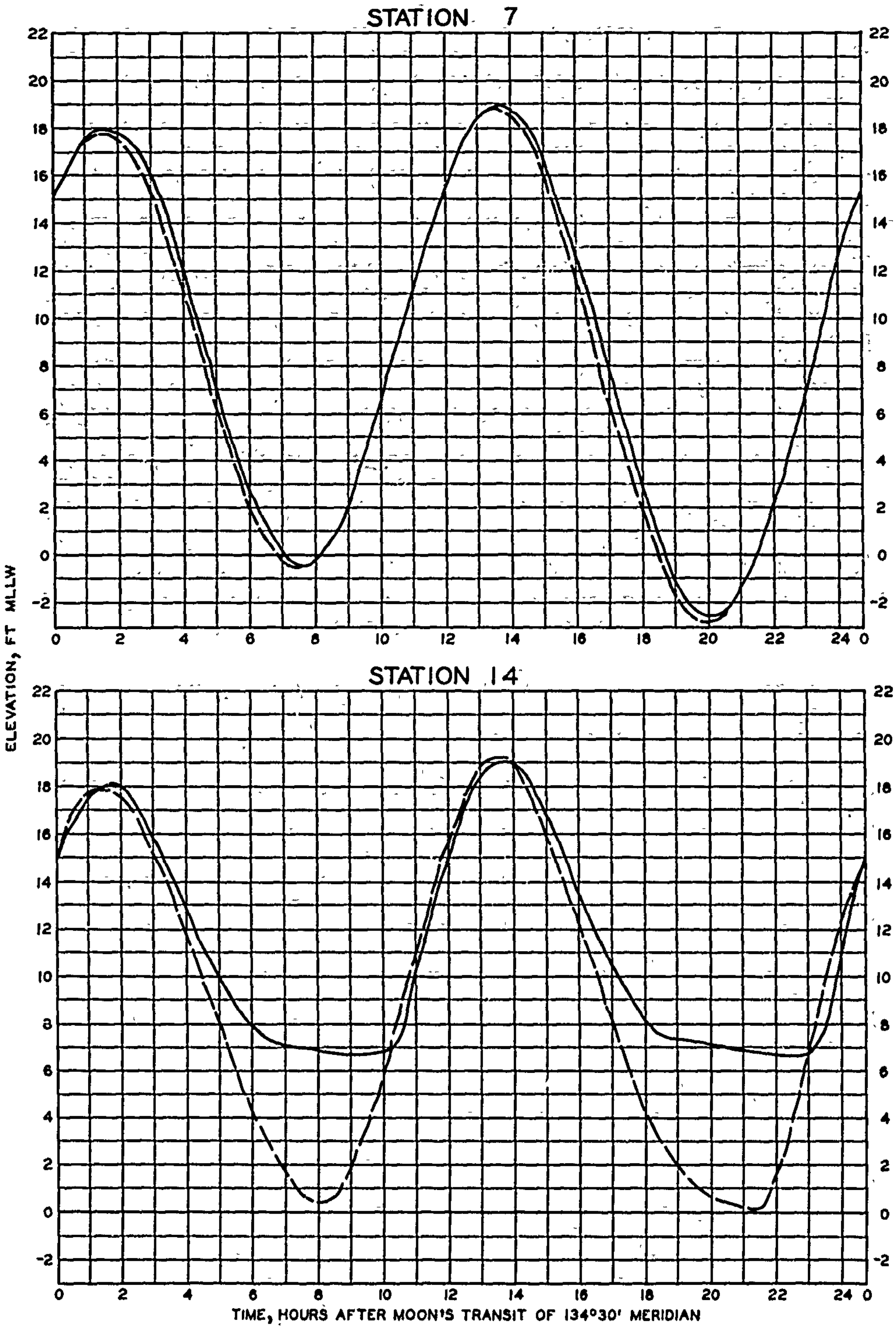
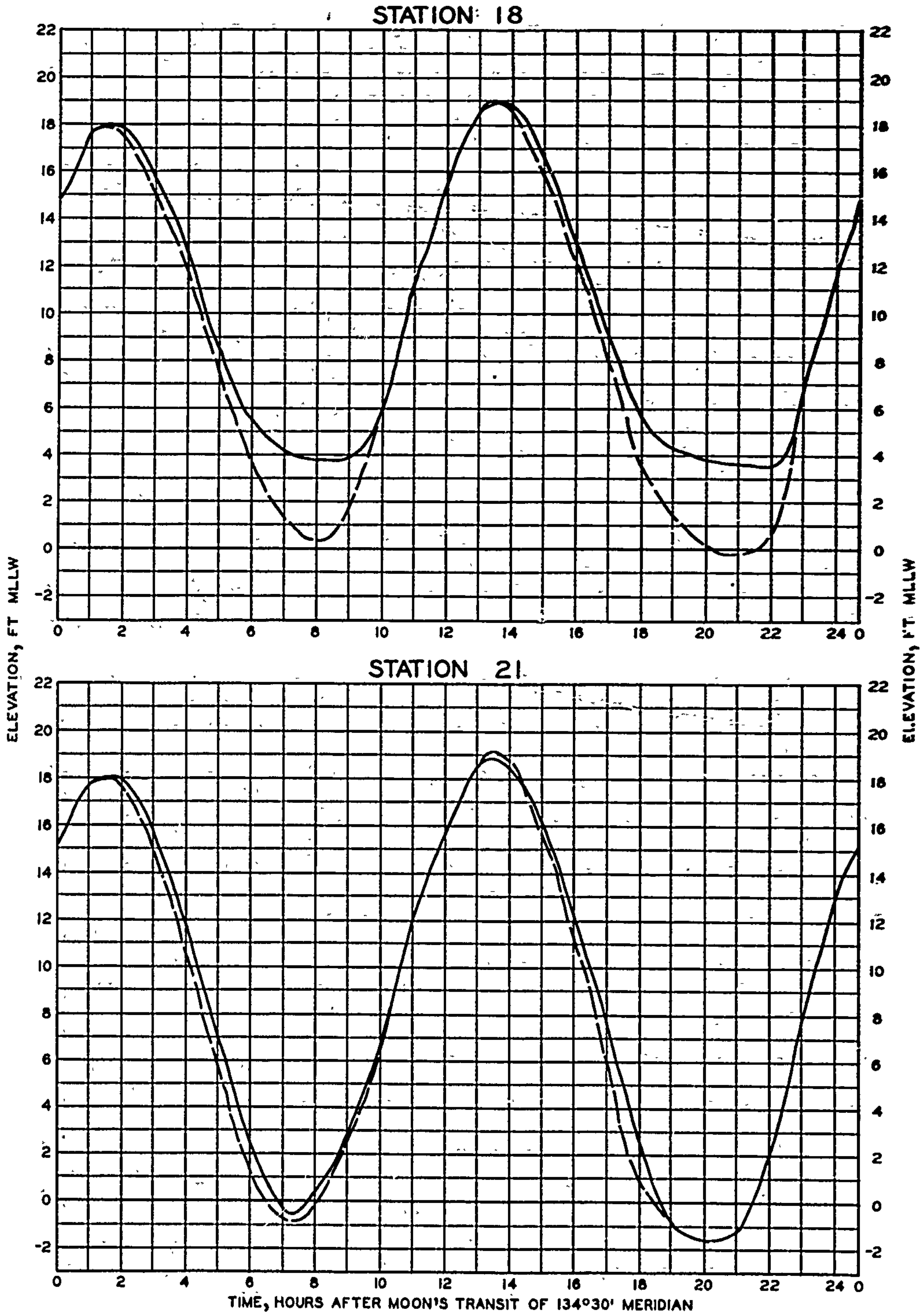

SHOALING DISTRIBUTION
BASE TEST
4- BY 75-FT CHANNEL
LEGEND
VERIFICATION (100.0%)
BASE TEST (143.6%)
SHOALING SECTIONS
PERCENT OF TOTAL SHOALING IN VERIFICATION

PLATE 14



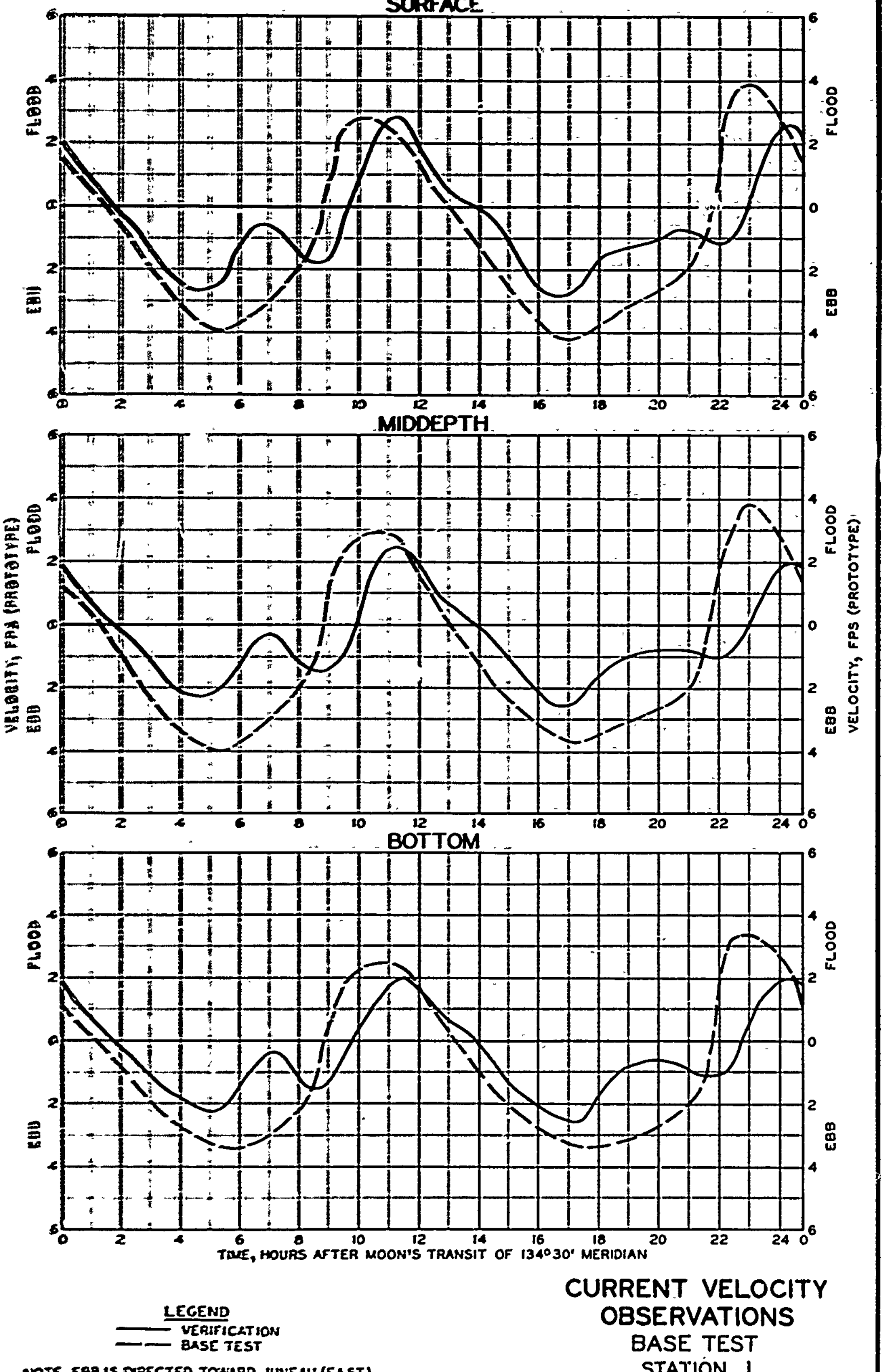
LEGEND
VERIFICATION
BASE TEST

TIDAL OBSERVATIONS
BASE TEST
STATIONS 7 AND 14
SPRING TIDE



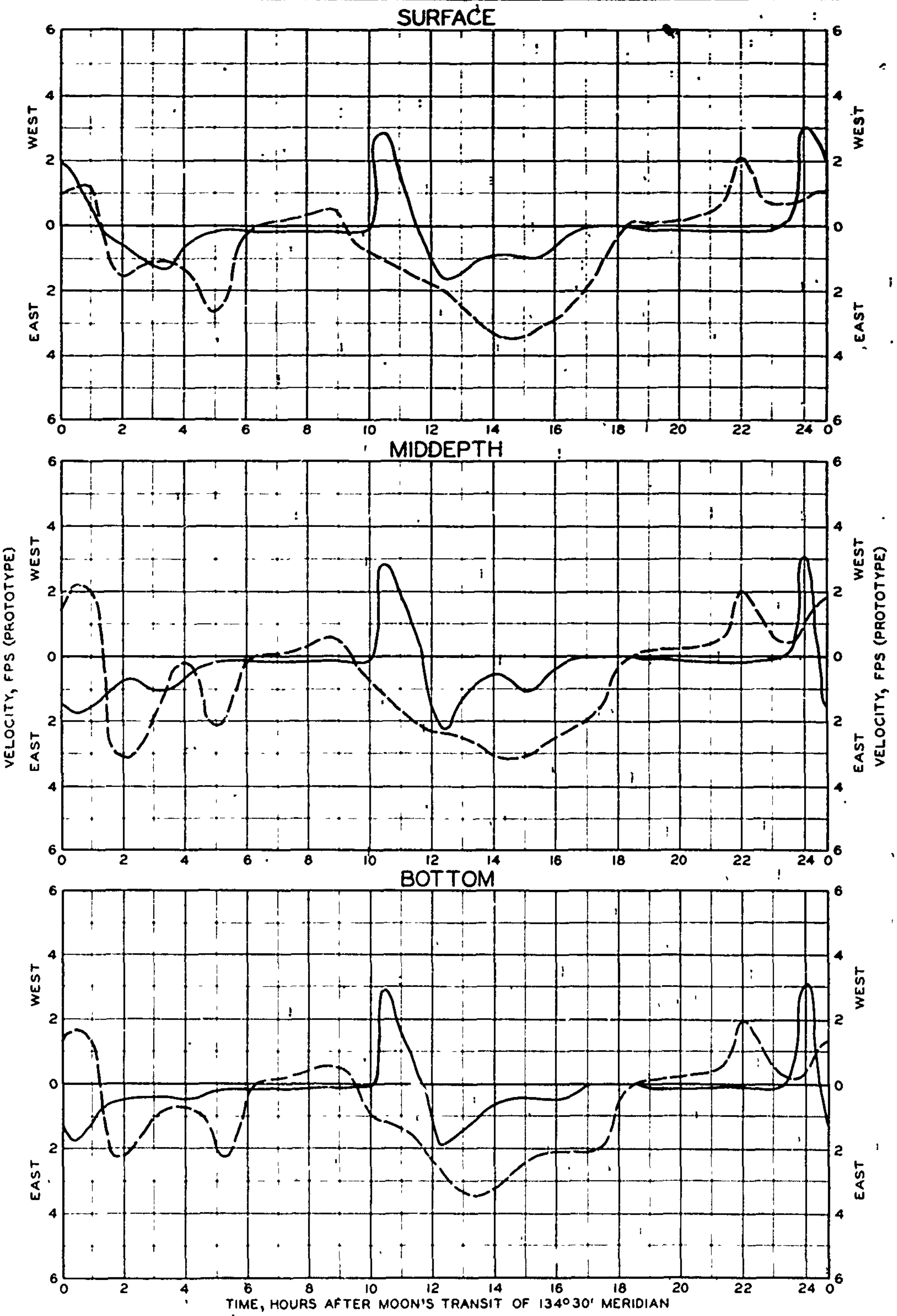
TIDAL OBSERVATIONS
BASE TEST
STATIONS 18 AND 21
SPRING TIDE

PLATE 16



CURRENT VELOCITY OBSERVATIONS
BASE TEST
STATION 1
SPRING TIDE

PLATE 17

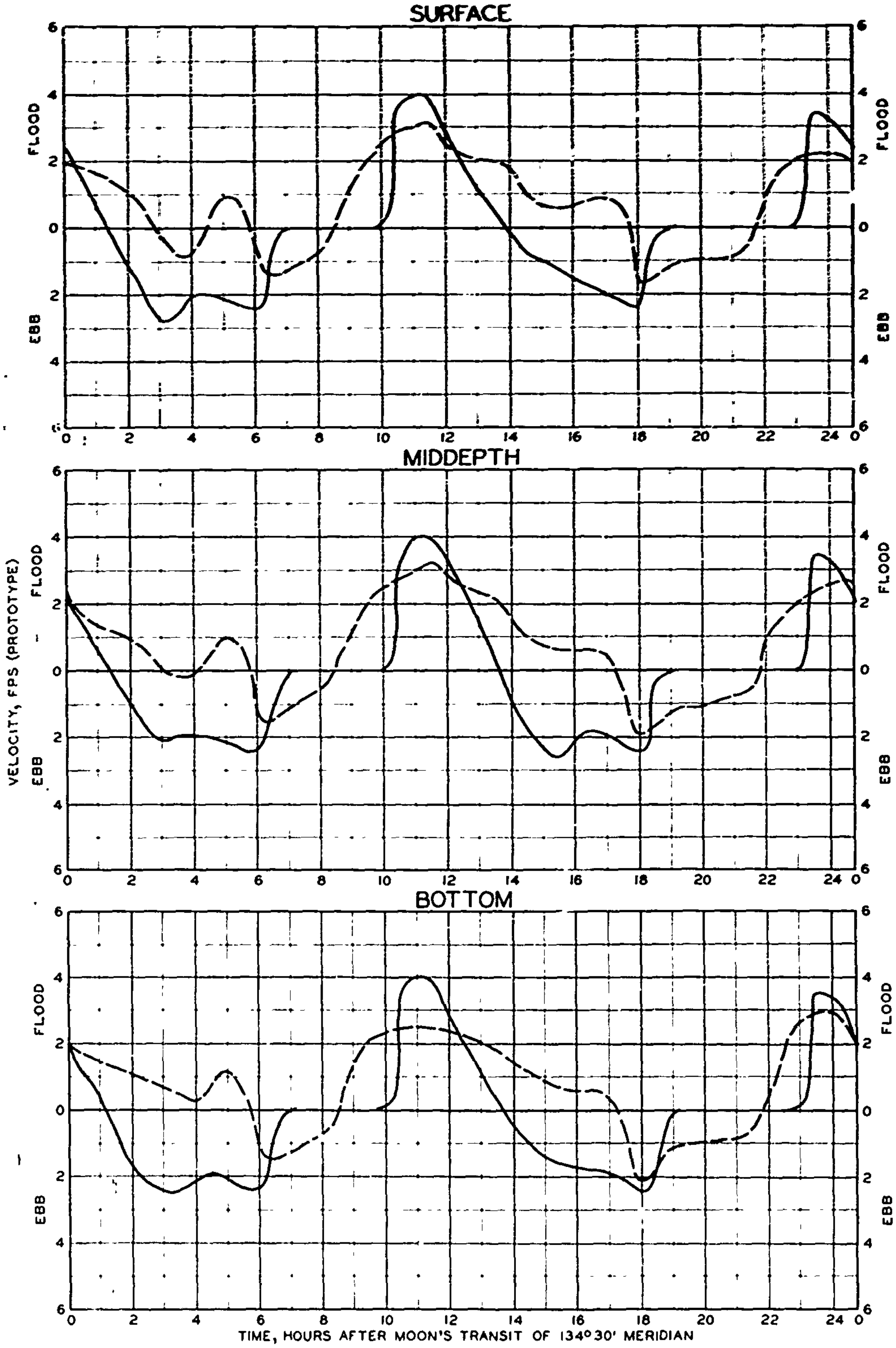


LEGEND
—— VERIFICATION
— — BASE TEST

NOTE EBB IS GENERALLY DIRECTED TOWARD JUNEAU (EAST)

CURRENT VELOCITY OBSERVATIONS
BASE TEST
STATION 2
SPRING TIDE

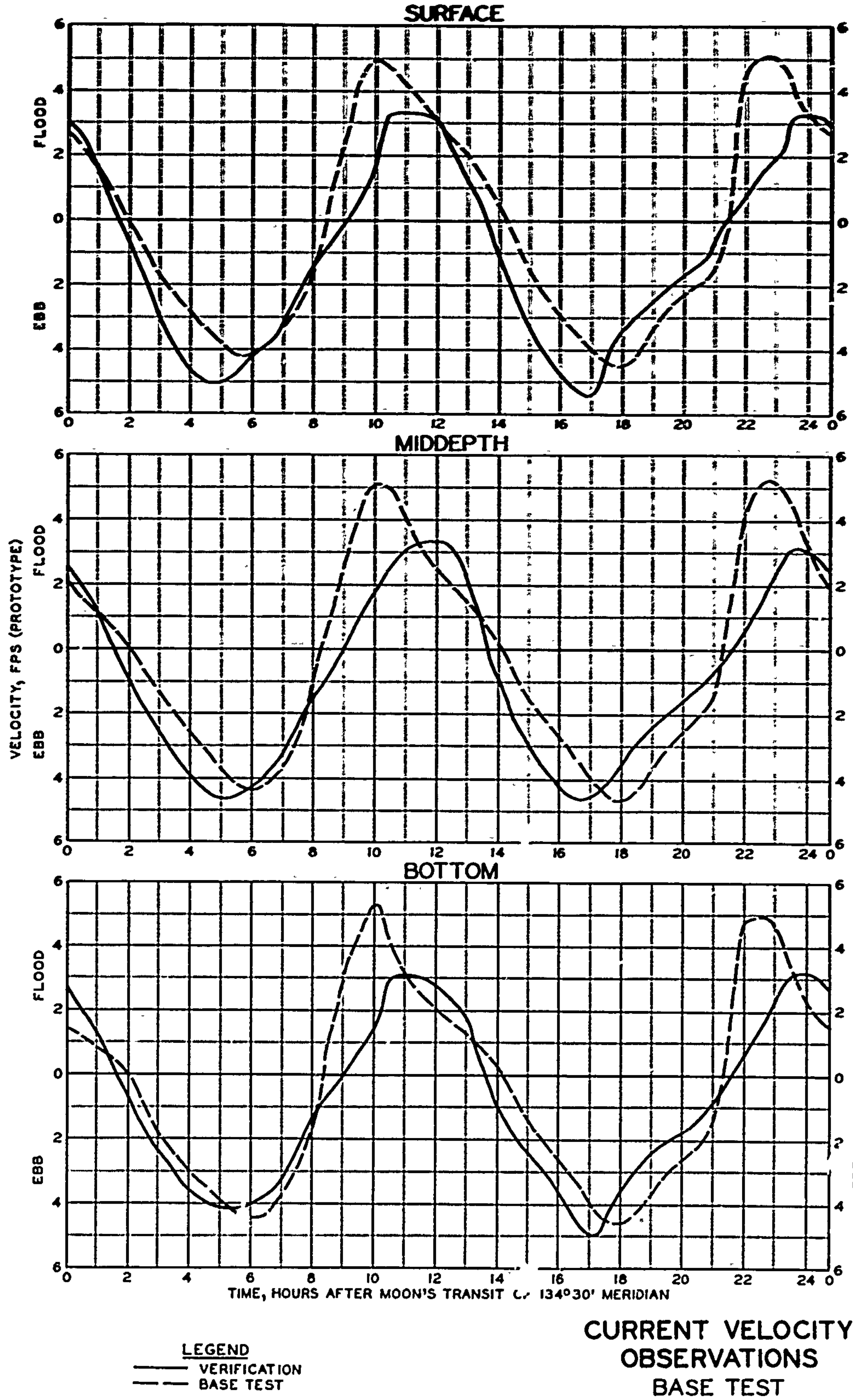
PLATE 18



LEGEND
——— VERIFICATION
— — BASE TEST

NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)

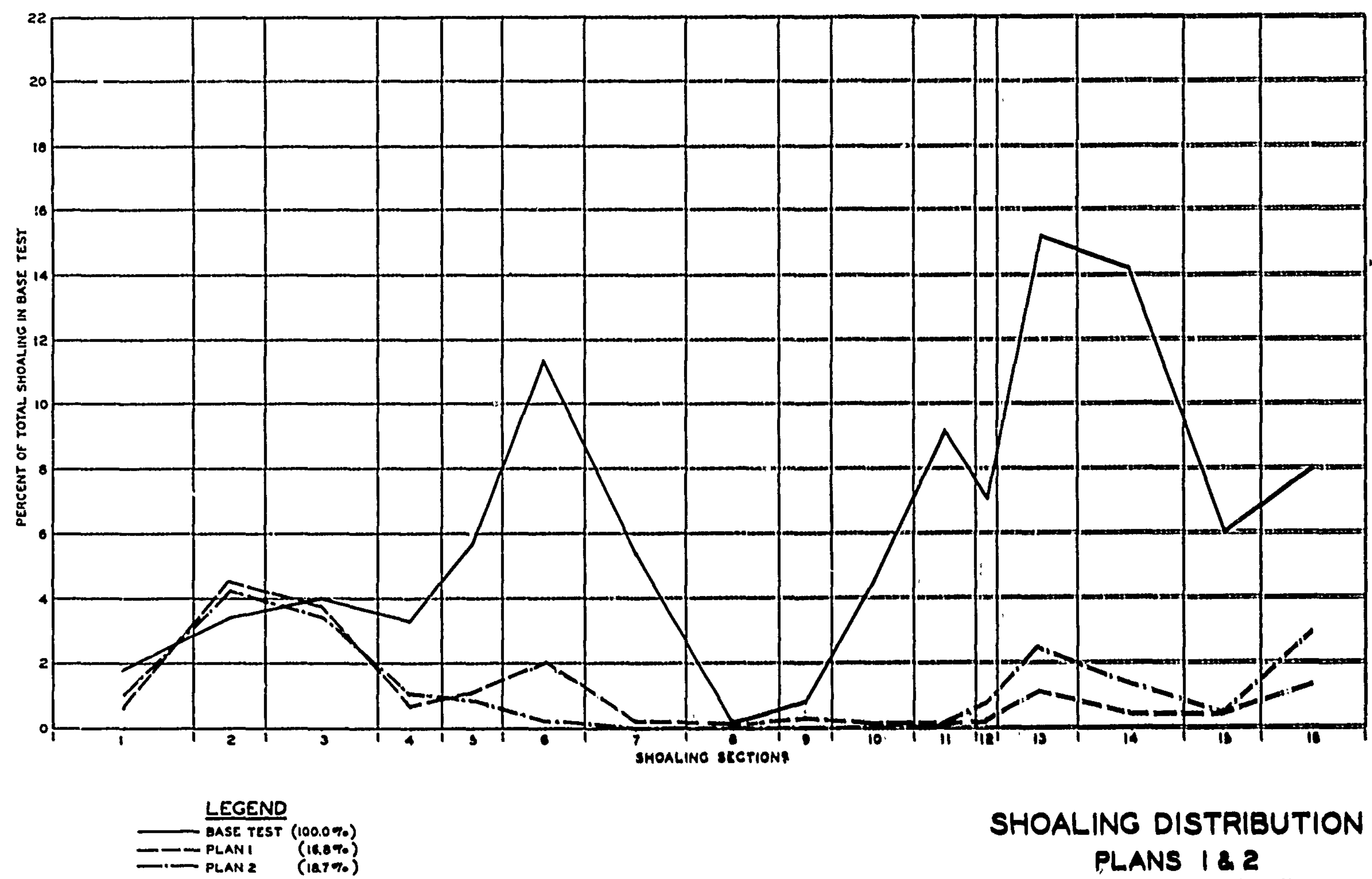
CURRENT VELOCITY OBSERVATIONS
BASE TEST
STATION 3
SPRING TIDE



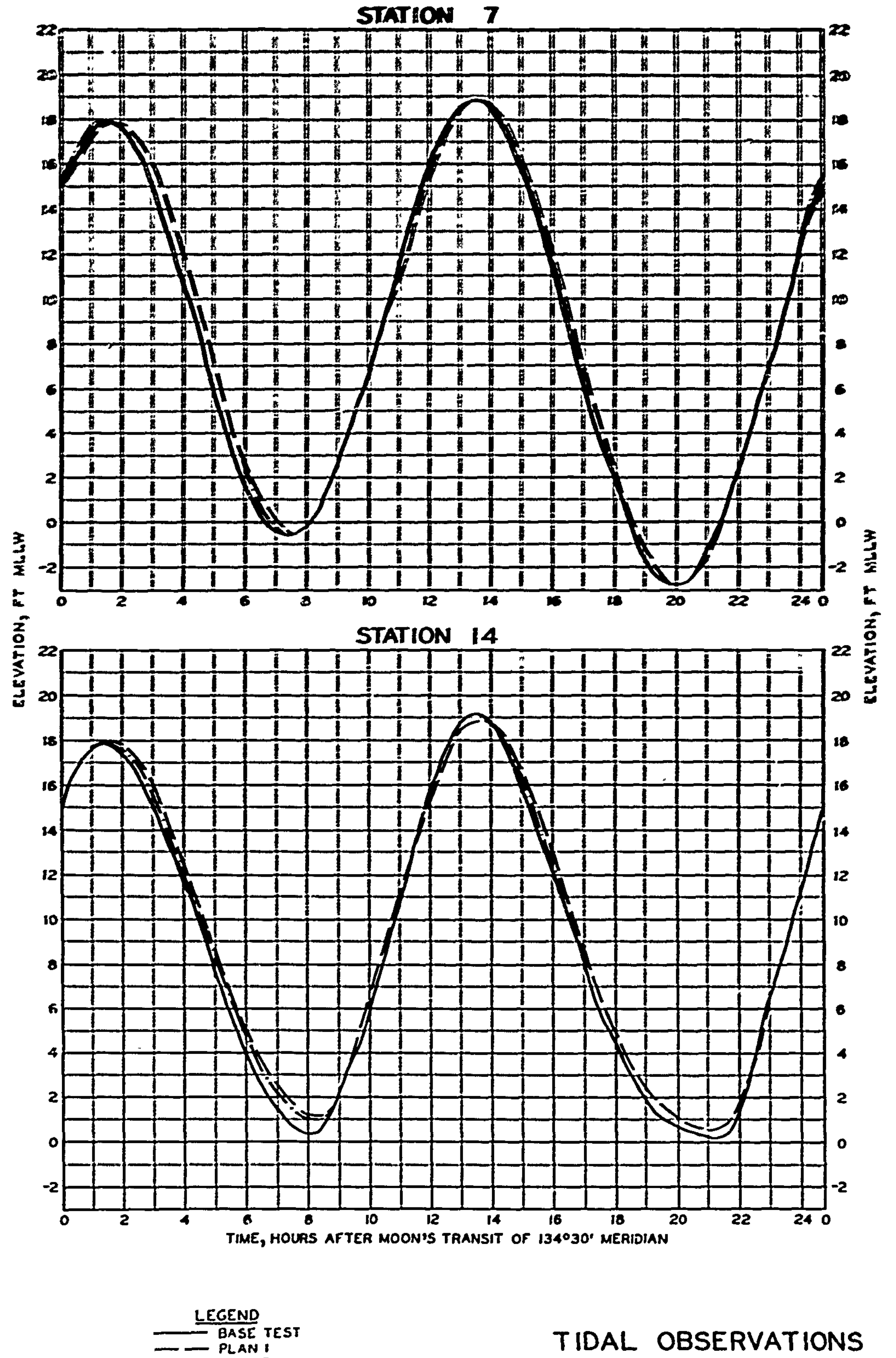
NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)

CURRENT VELOCITY OBSERVATIONS
BASE TEST
STATION 4
SPRING TIDE

PLATE 20

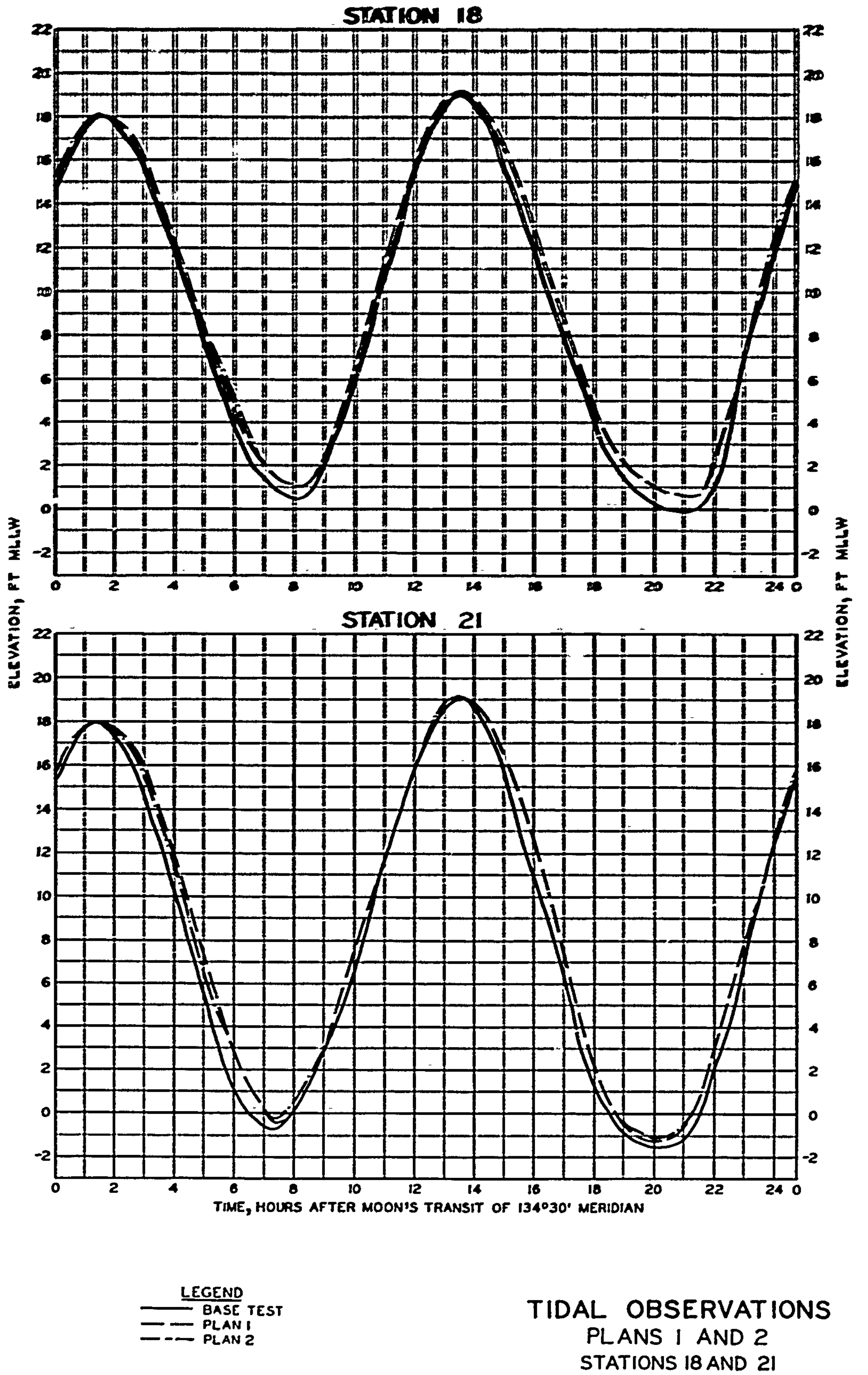


SHOALING DISTRIBUTION
PLANS 1 & 2
4- BY 75-FT CHANNEL

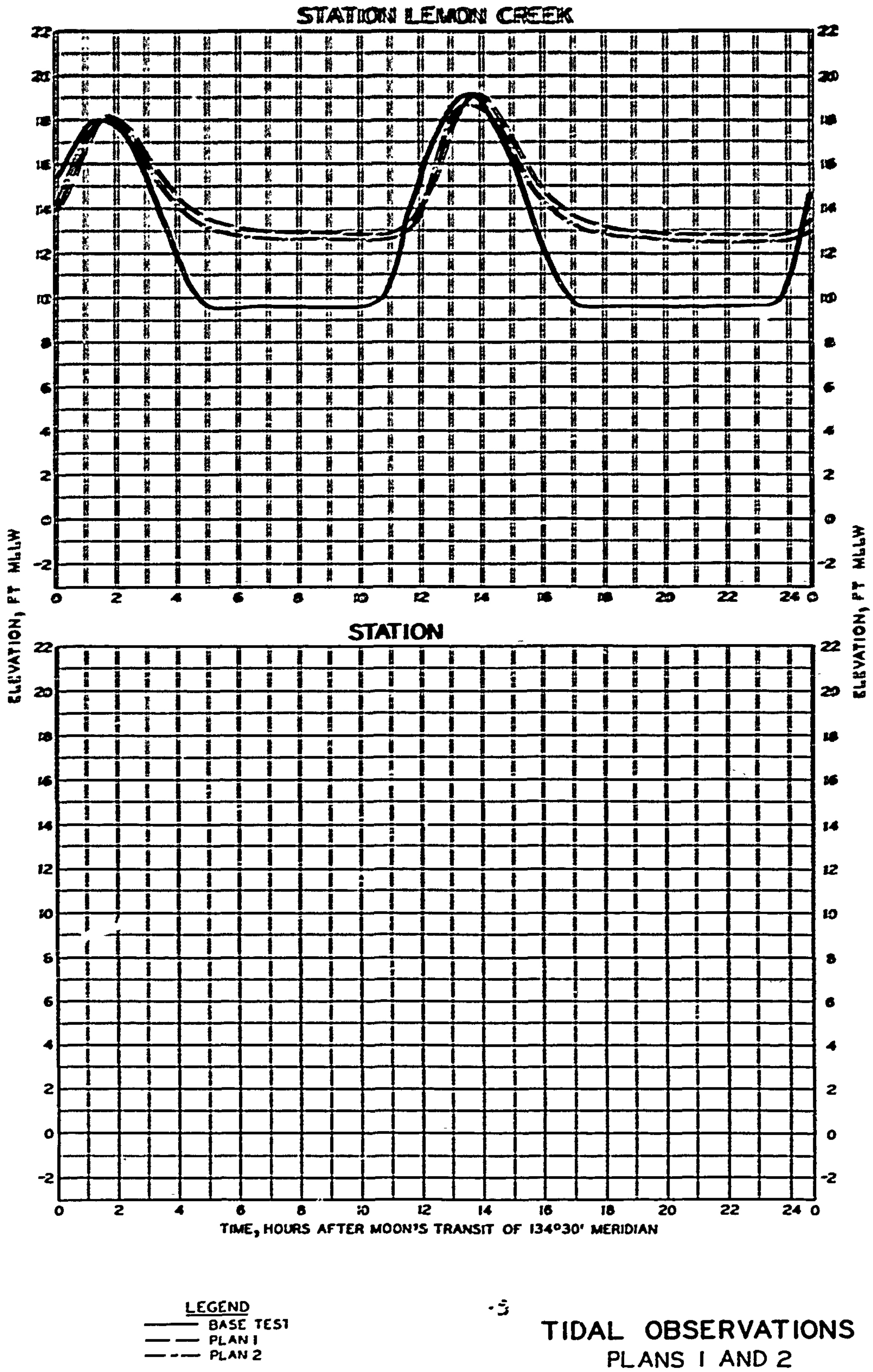


TIDAL OBSERVATIONS
PLANS 1 AND 2
STATIONS 7 AND 14
SPRING TIDE

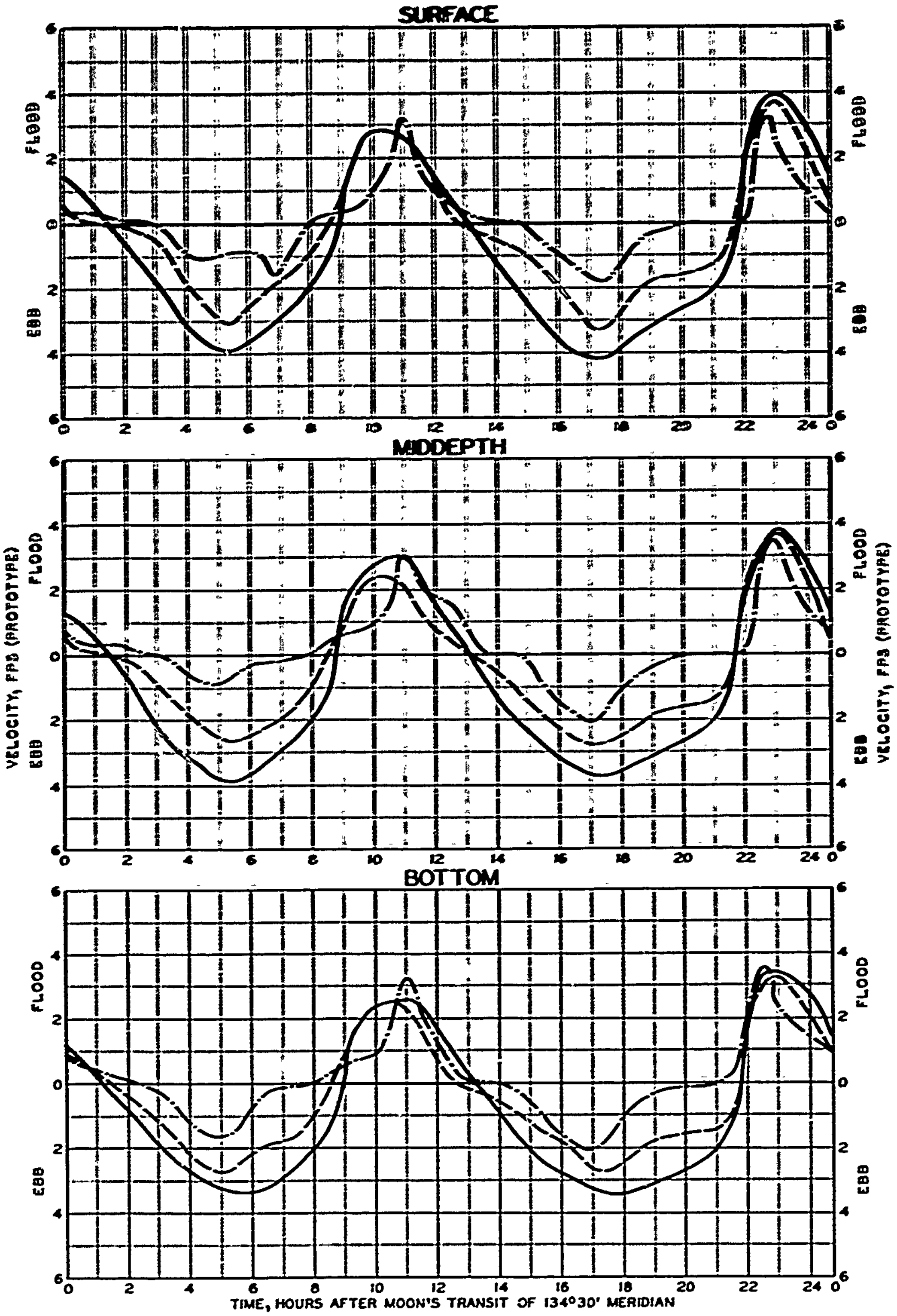
PLATE 22



TIDAL OBSERVATIONS
PLANS 1 AND 2
STATIONS 18 AND 21
SPRING TIDE



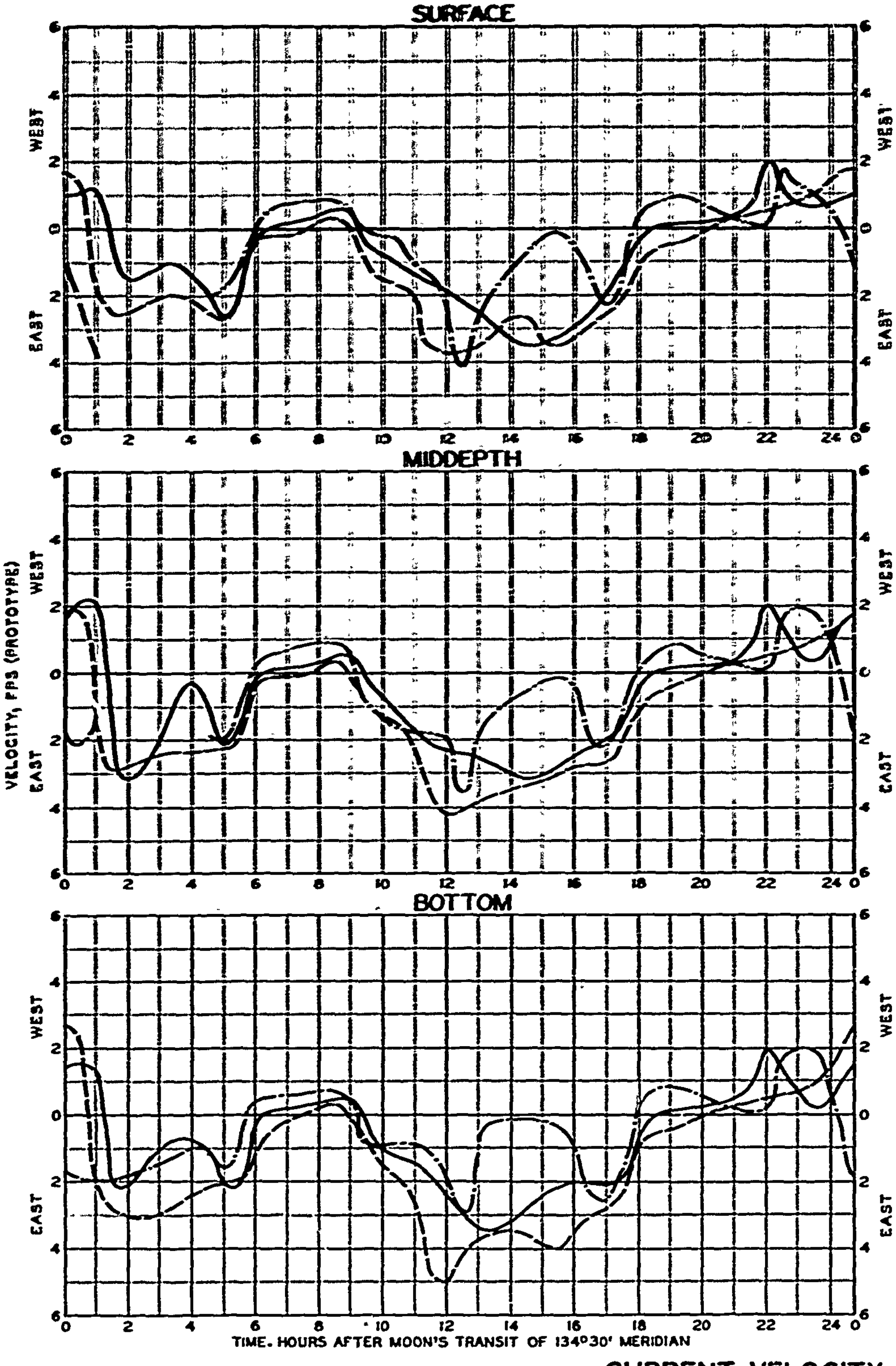
TIDAL OBSERVATIONS
PLANS 1 AND 2
STATION LEMON CREEK
SPRING TIDE



LEGEND
——— BASE TEST
— — PLAN 1
—·— PLAN 4

NOTE: EBB IS DIRECTED TOWARD JUNEAU (EAST)

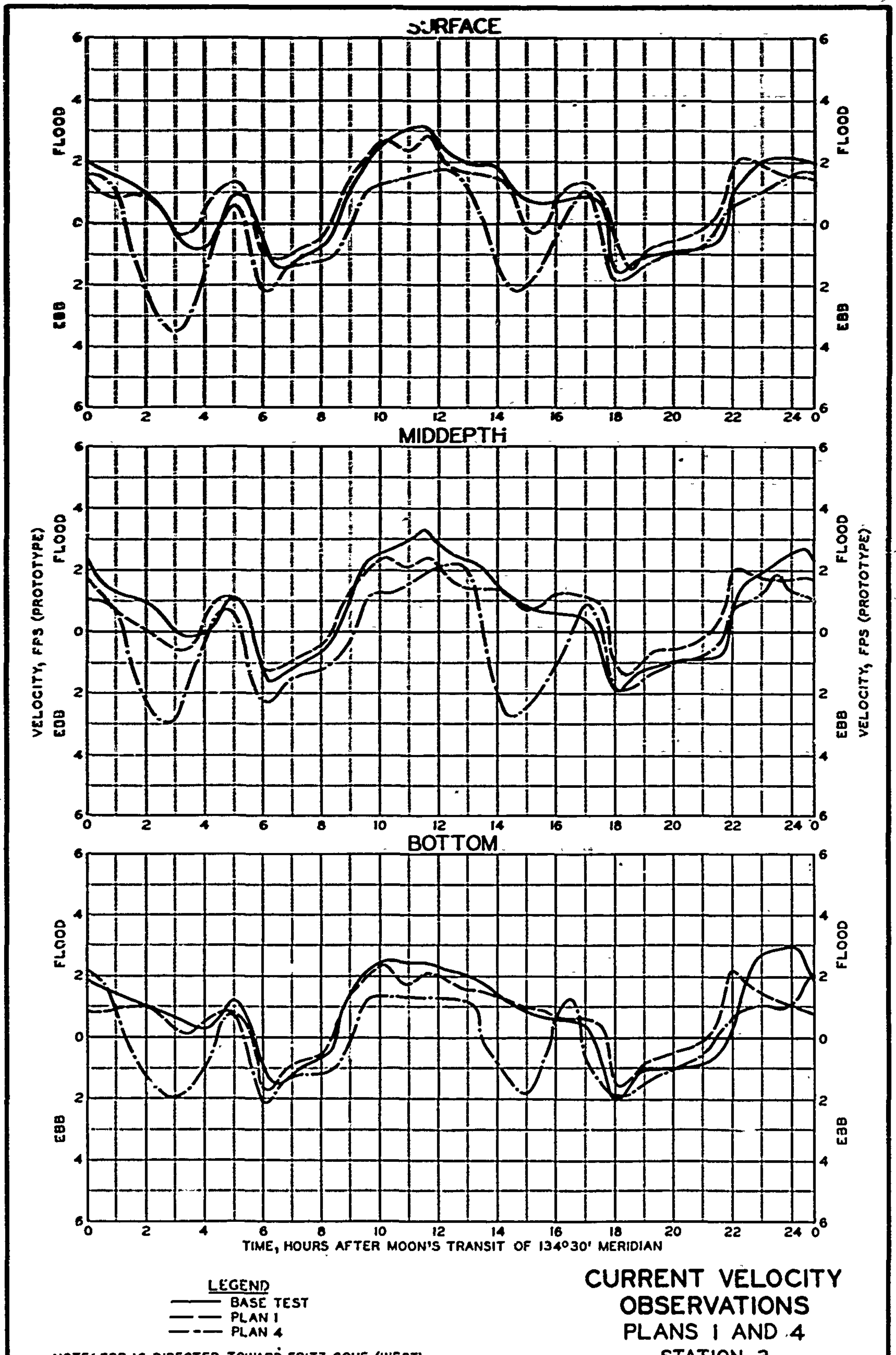
CURRENT VELOCITY OBSERVATIONS
PLANS 1 AND 4
STATION 1
SPRING TIDE



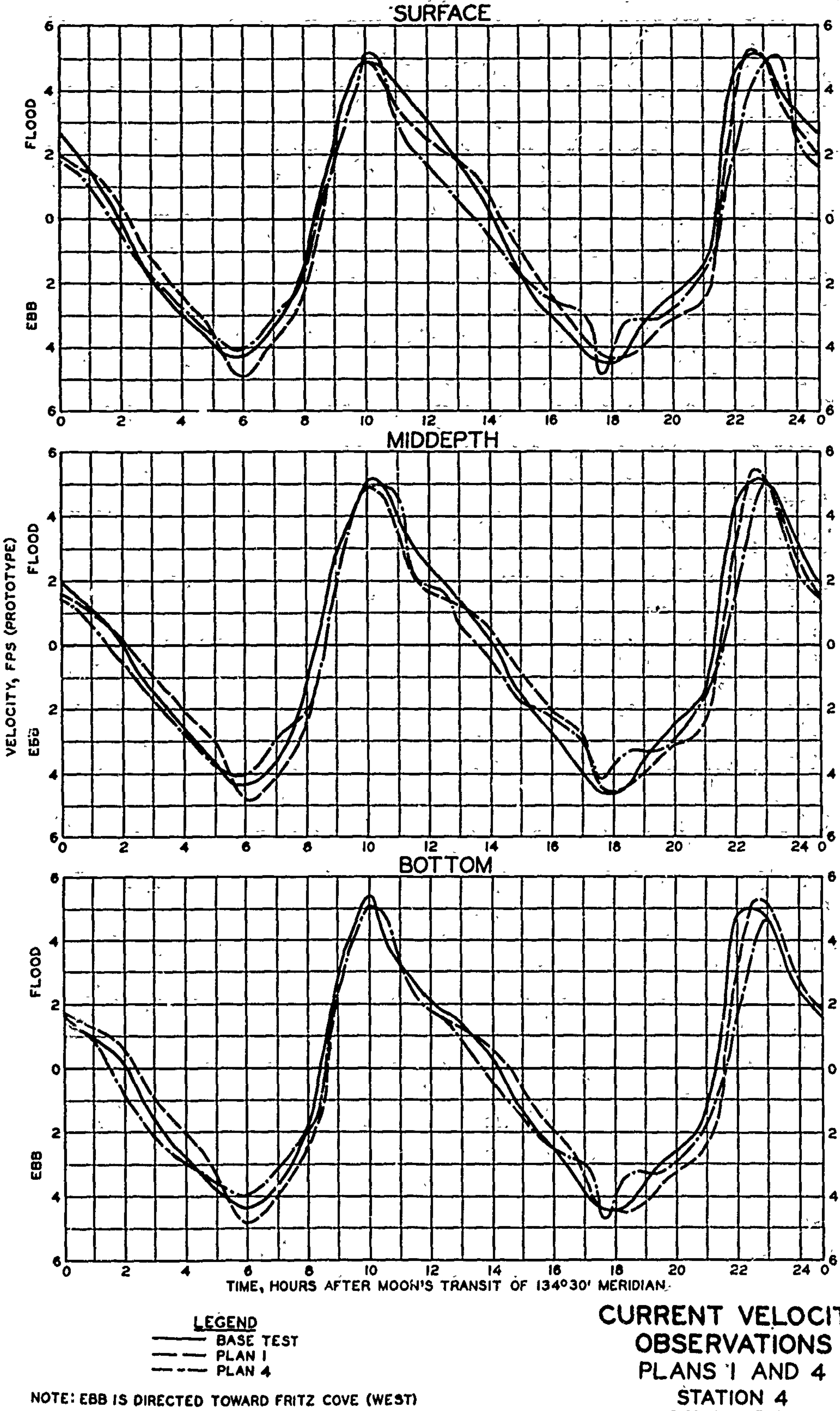
LEGEND
BASE TEST
PLAN 1
PLAN 4

NOTE: EBB IS GENERALLY DIRECTED TOWARD JUNEAU (EAST)

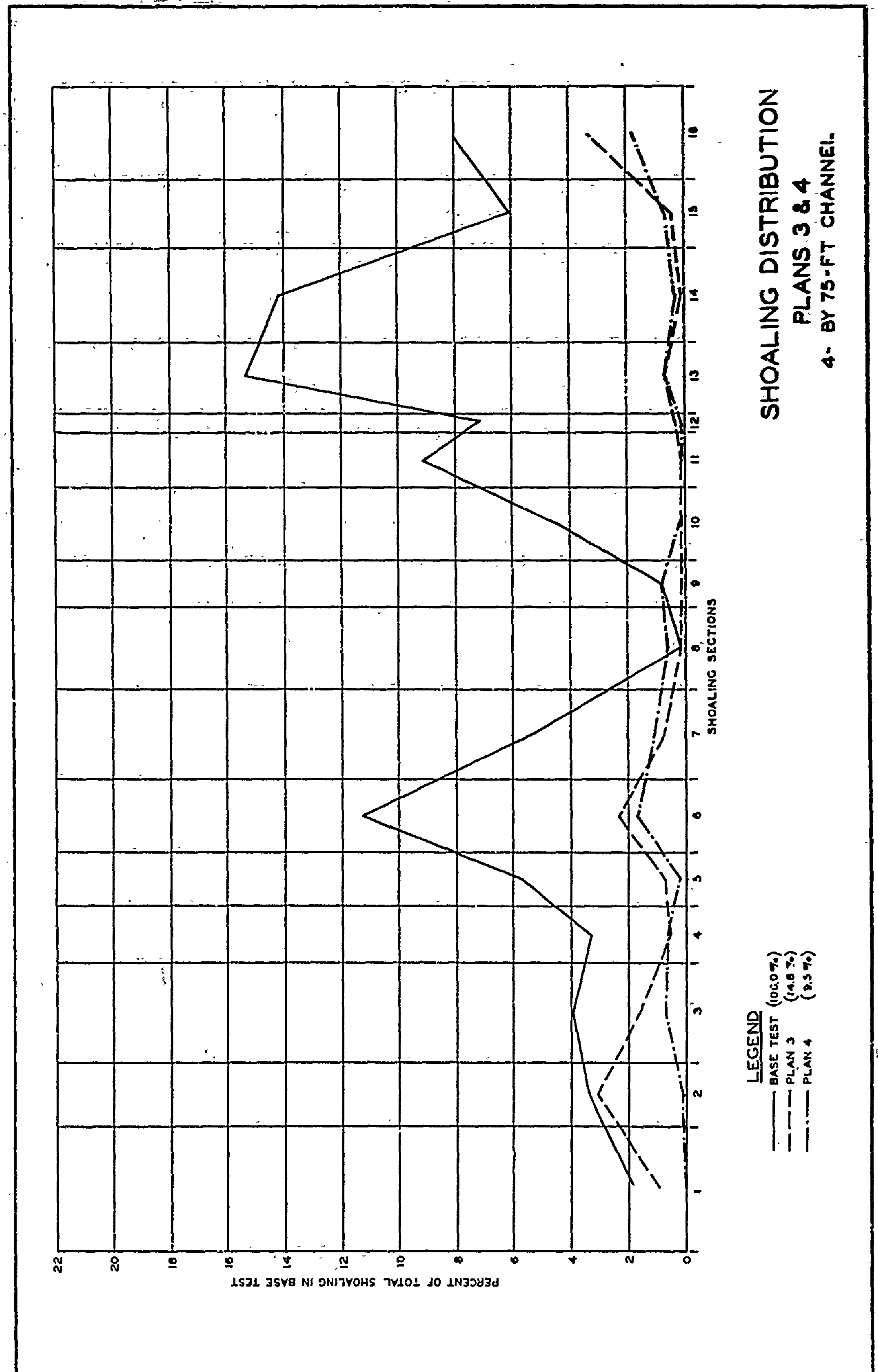
CURRENT VELOCITY OBSERVATIONS
PLANS 1 AND 4
STATION 2
SPRING TIDE



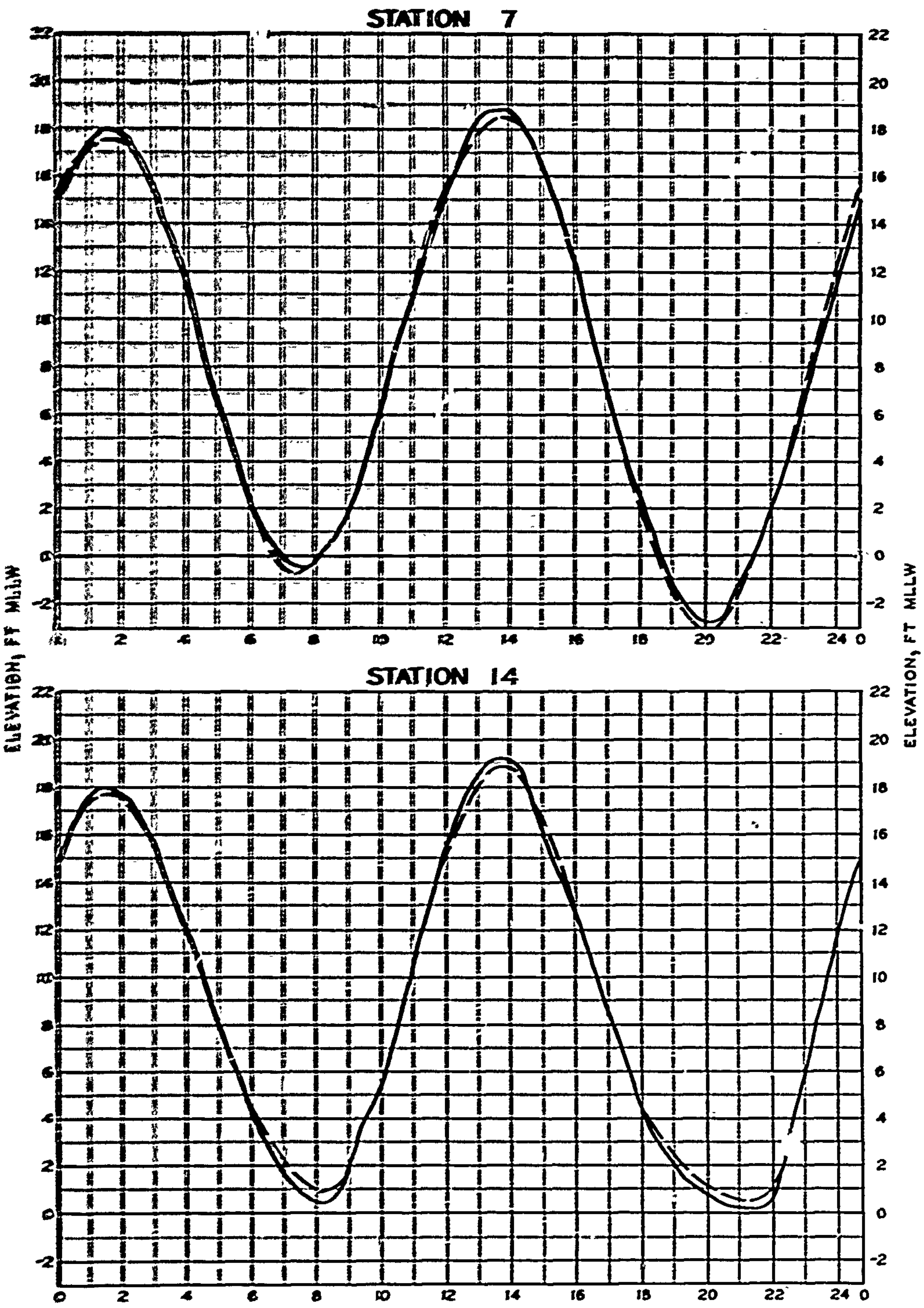
CURRENT VELOCITY OBSERVATIONS
PLANS 1 AND 4
STATION 3
SPRING TIDE



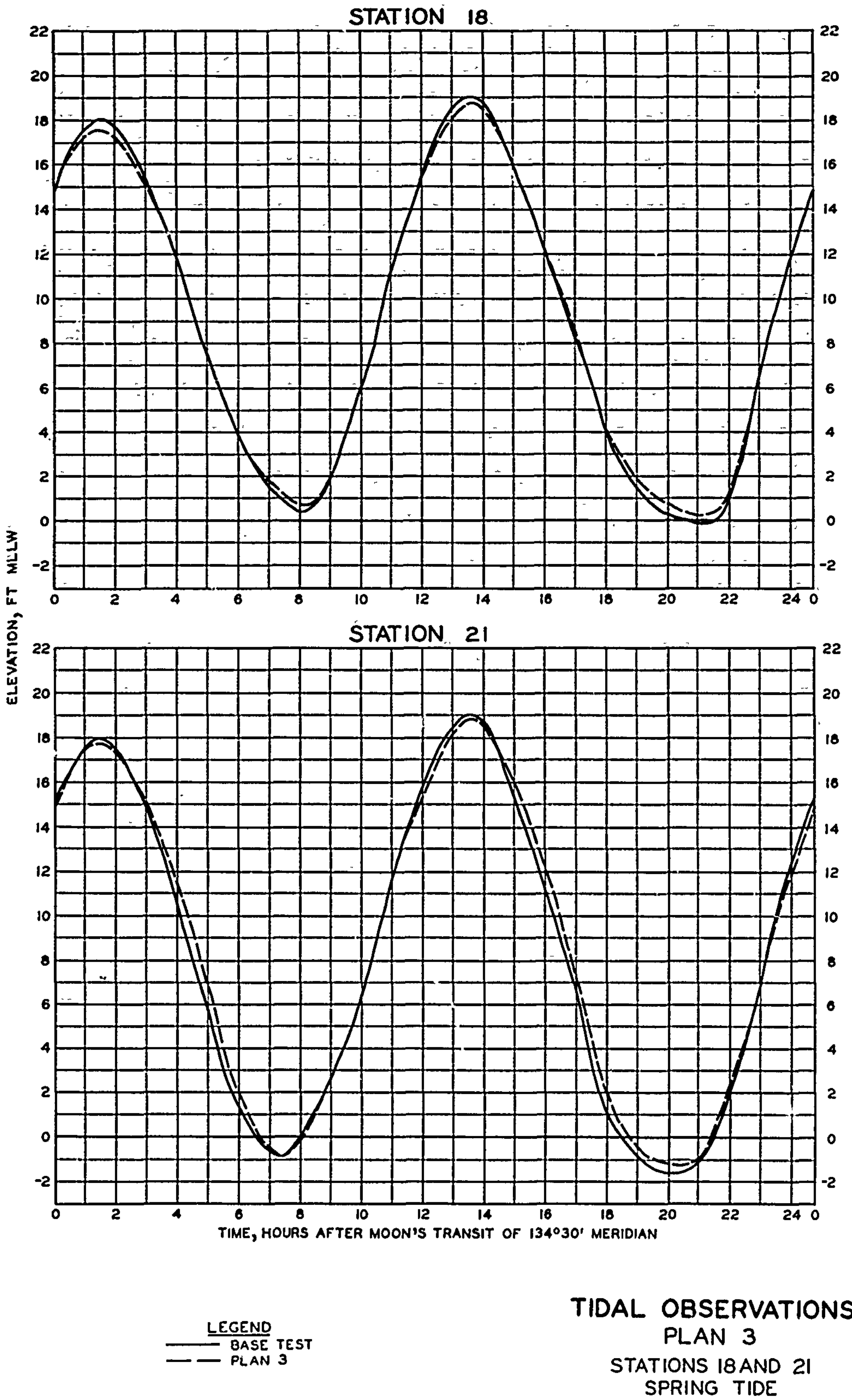
CURRENT VELOCITY OBSERVATIONS
PLANS 1 AND 4
STATION 4
SPRING TIDE



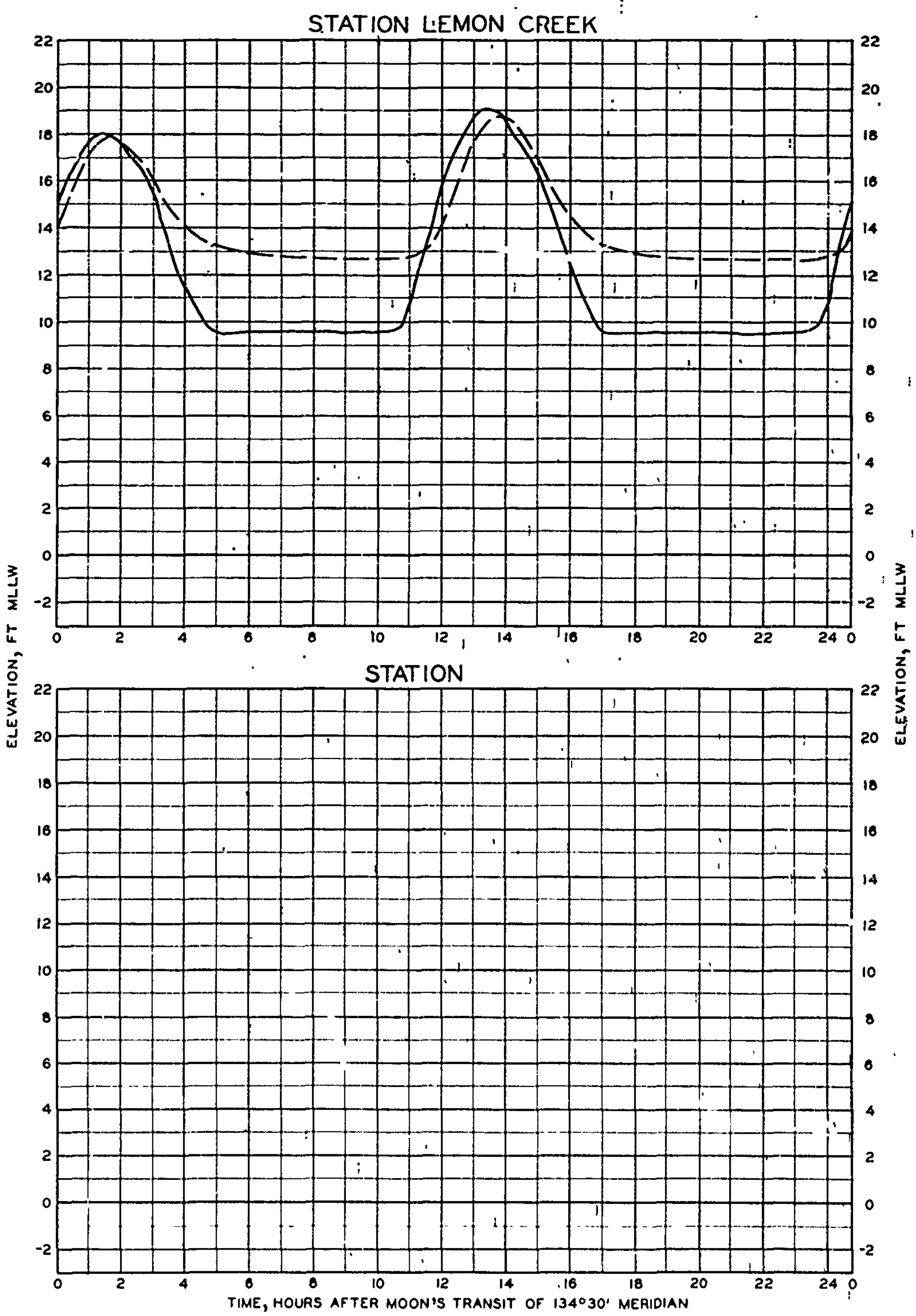
SHOALING DISTRIBUTION
PLANS 3 & 4
4- BY 75-FT CHANNEL.
LEGEND
BASE TEST (100.0%)
PLAN 3 (14.8%)
PLAN 4 (9.5%)
SHOALING SECTIONS
PERCENT OF TOTAL SHOALING IN BASE TEST
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0 2 4 6 8 10 12 14 16 18 20 22



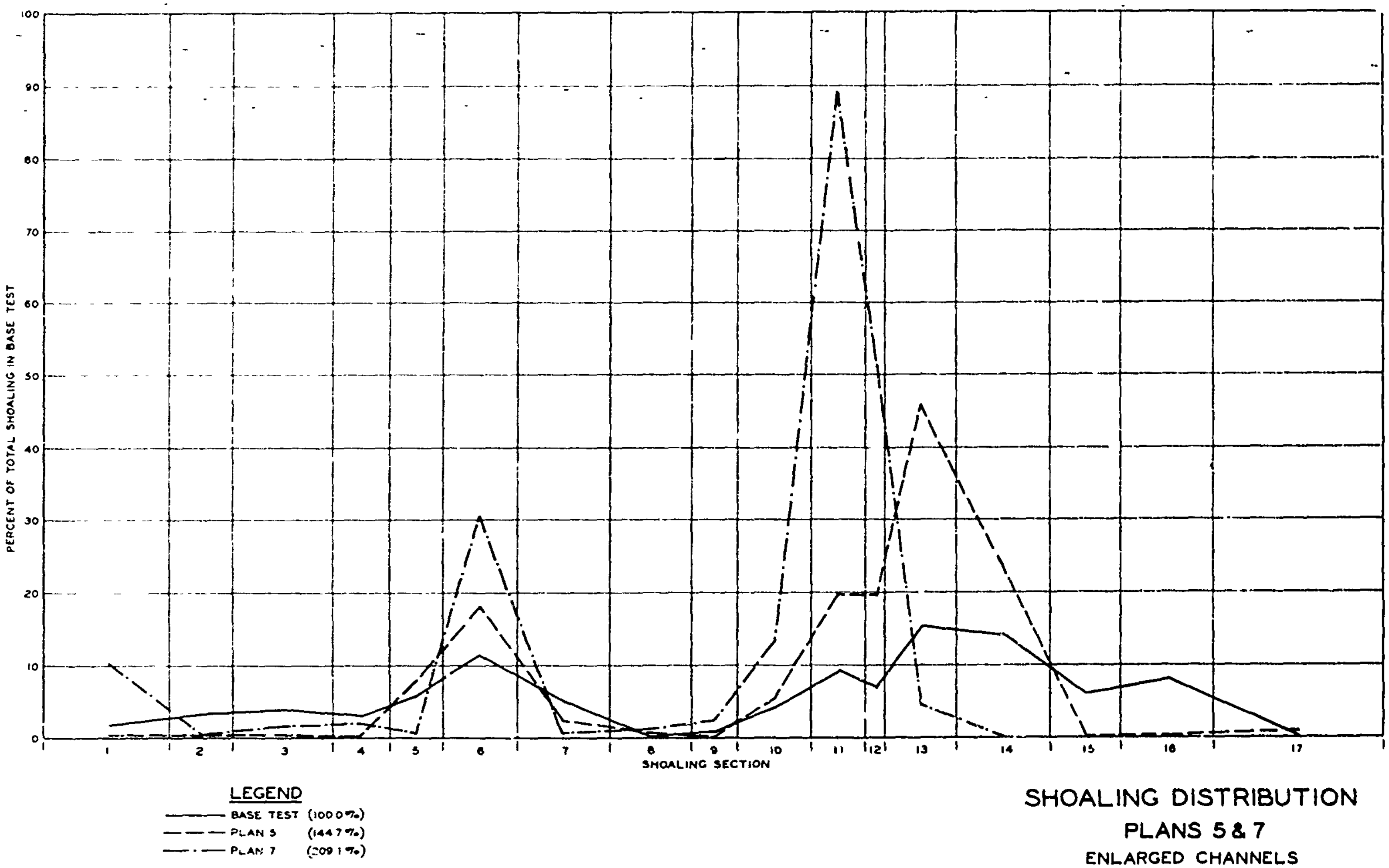
TIDAL OBSERVATIONS
PLAN 3
STATIONS 7 AND 14
SPRING TIDE



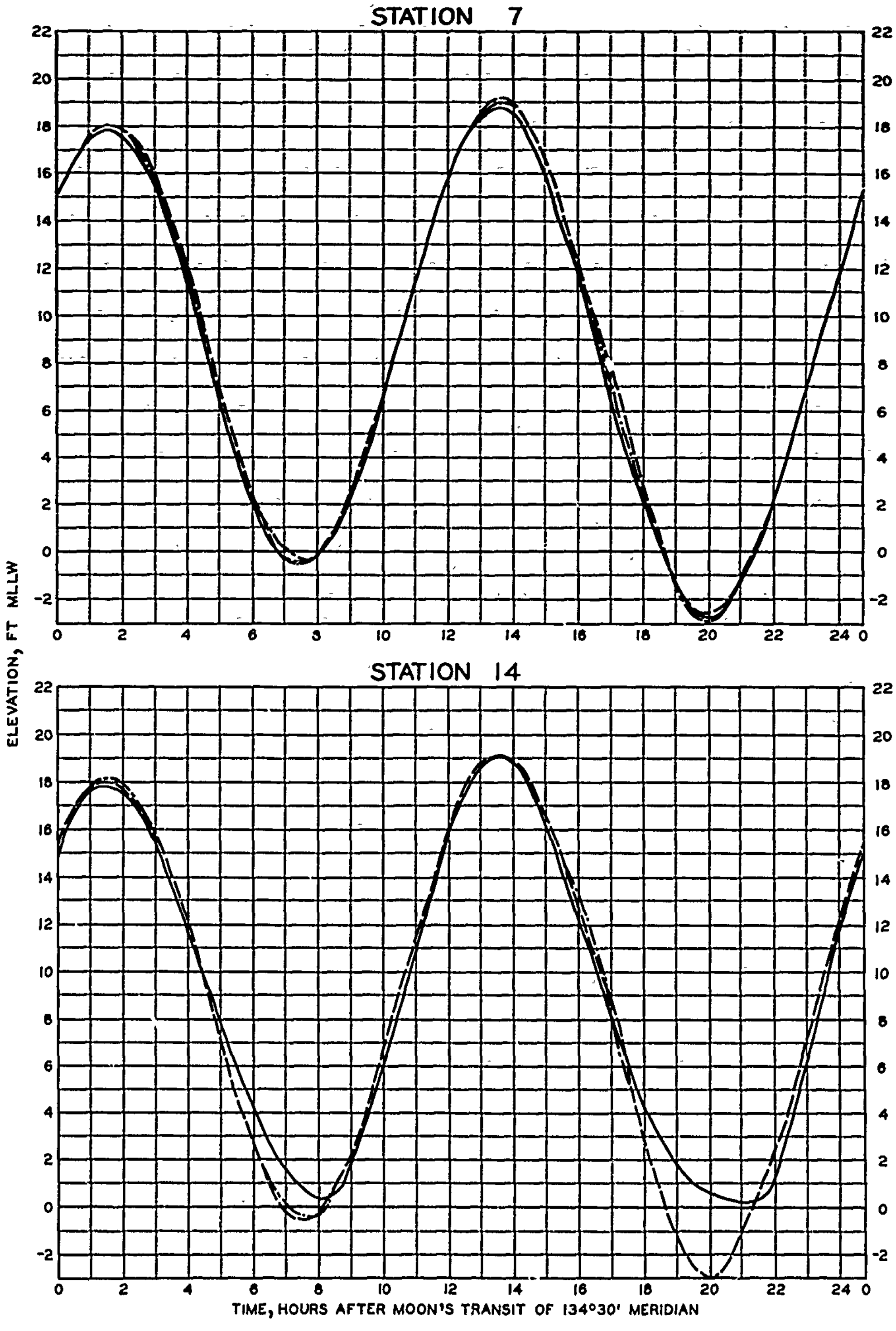
TIDAL OBSERVATIONS
PLAN 3
STATIONS 18 AND 21
SPRING TIDE



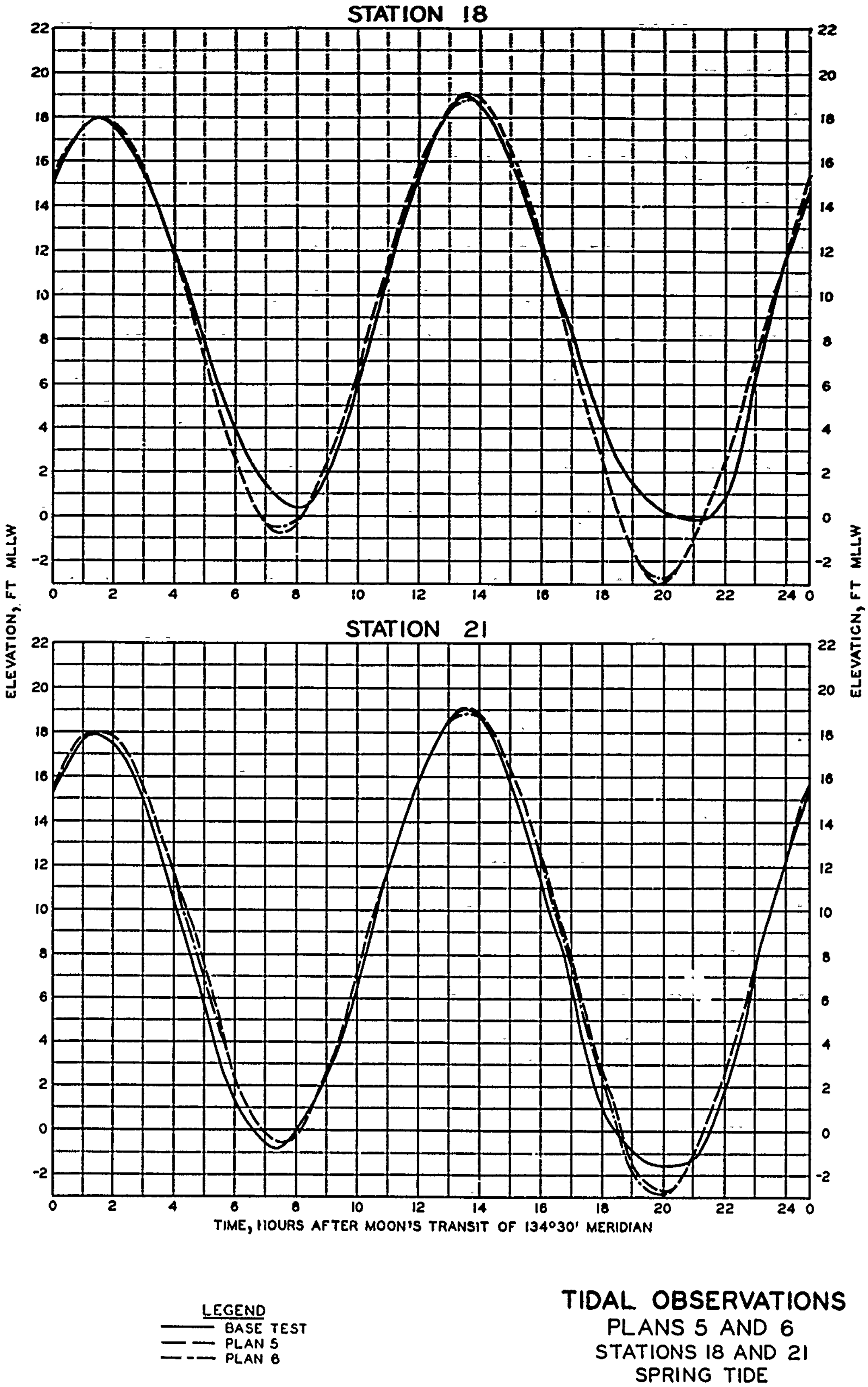
TIDAL OBSERVATIONS
PLAN 3
STATION LEMON CREEK
SPRING TIDE



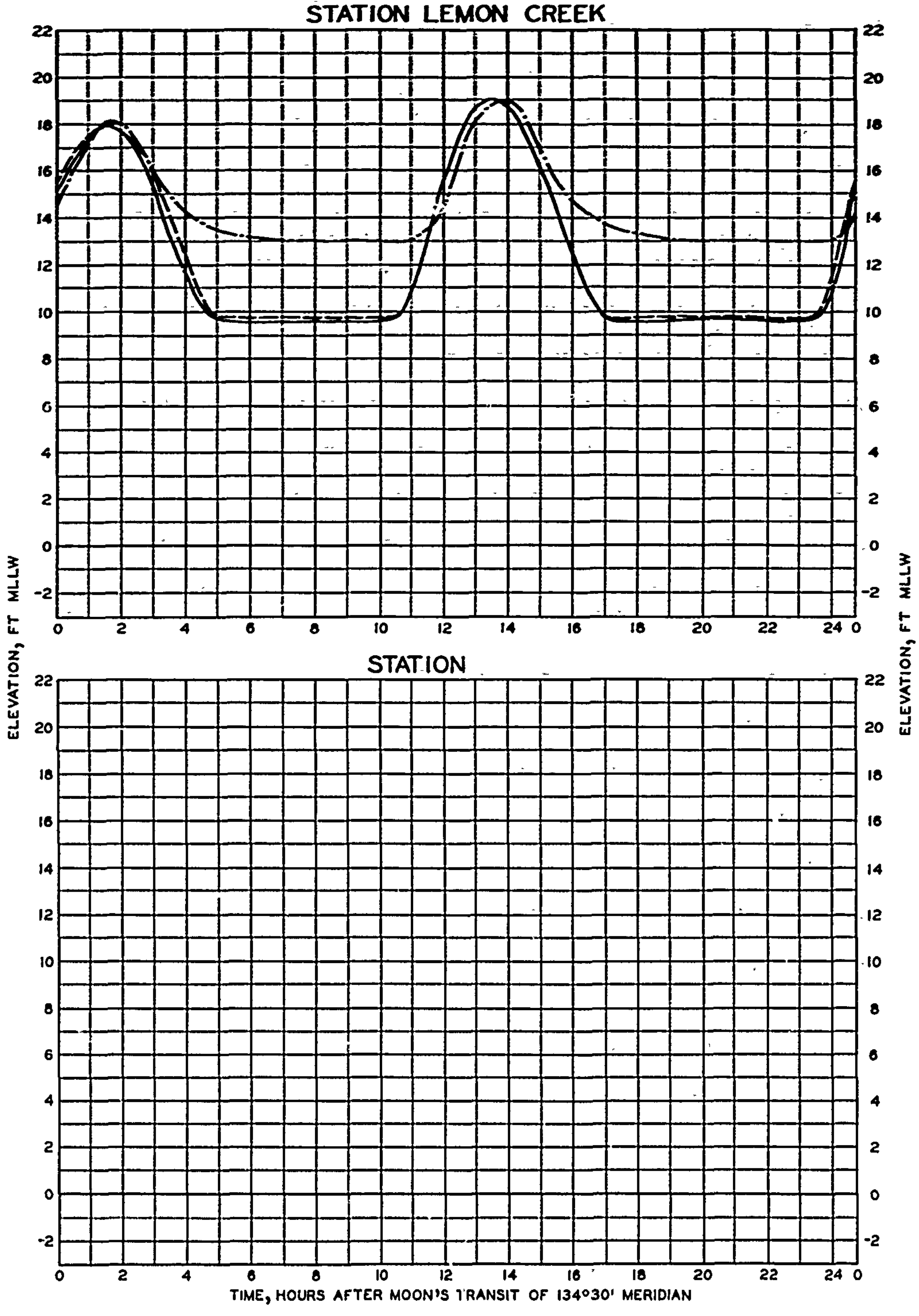
SHOALING DISTRIBUTION
PLANS 5 & 7
ENLARGED CHANNELS



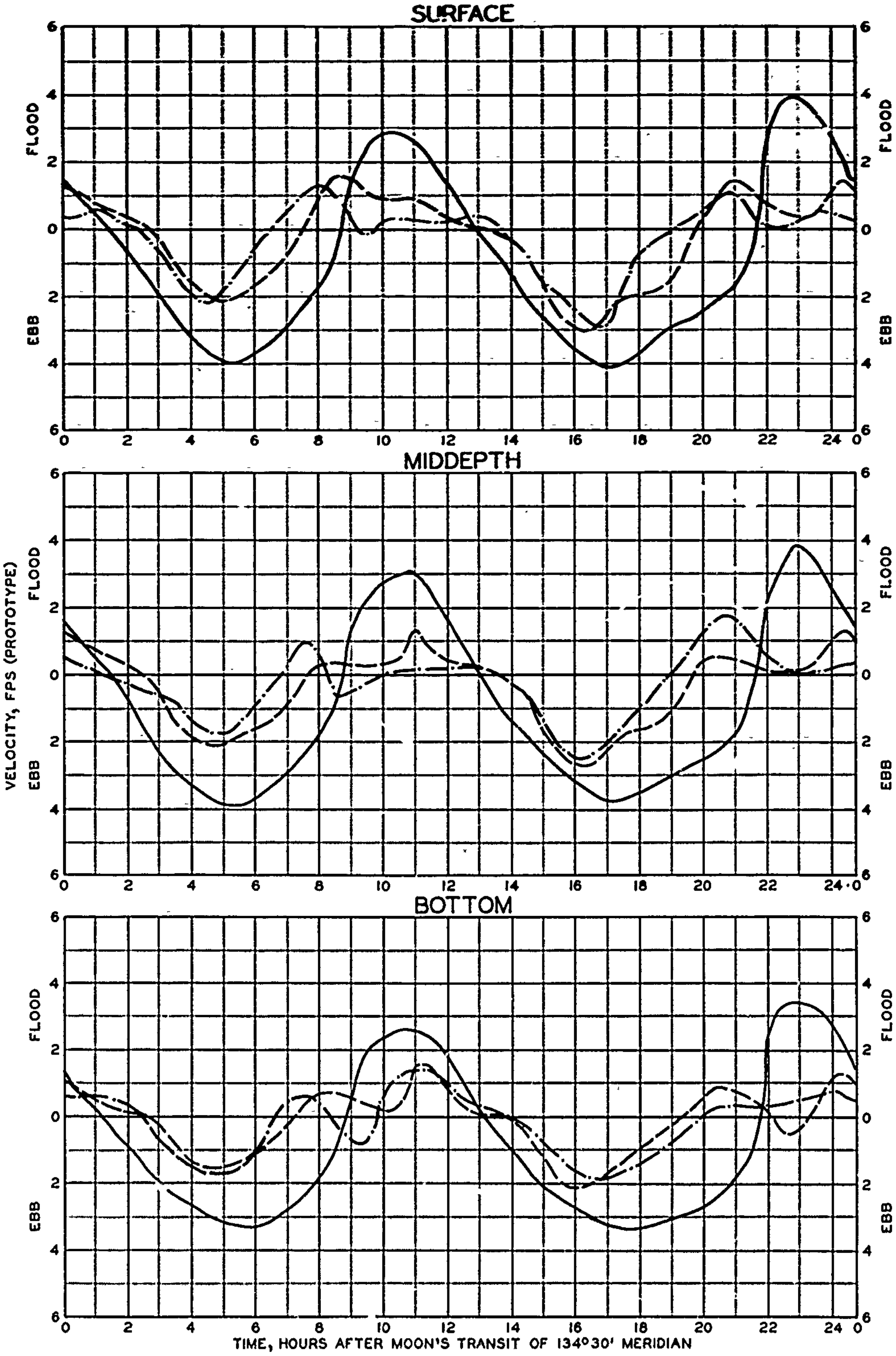
TIDAL OBSERVATIONS
PLANS 5 AND 6
STATIONS 7 AND 14
SPRING TIDE



TIDAL OBSERVATIONS
PLANS 5 AND 6
STATIONS 18 AND 21
SPRING TIDE



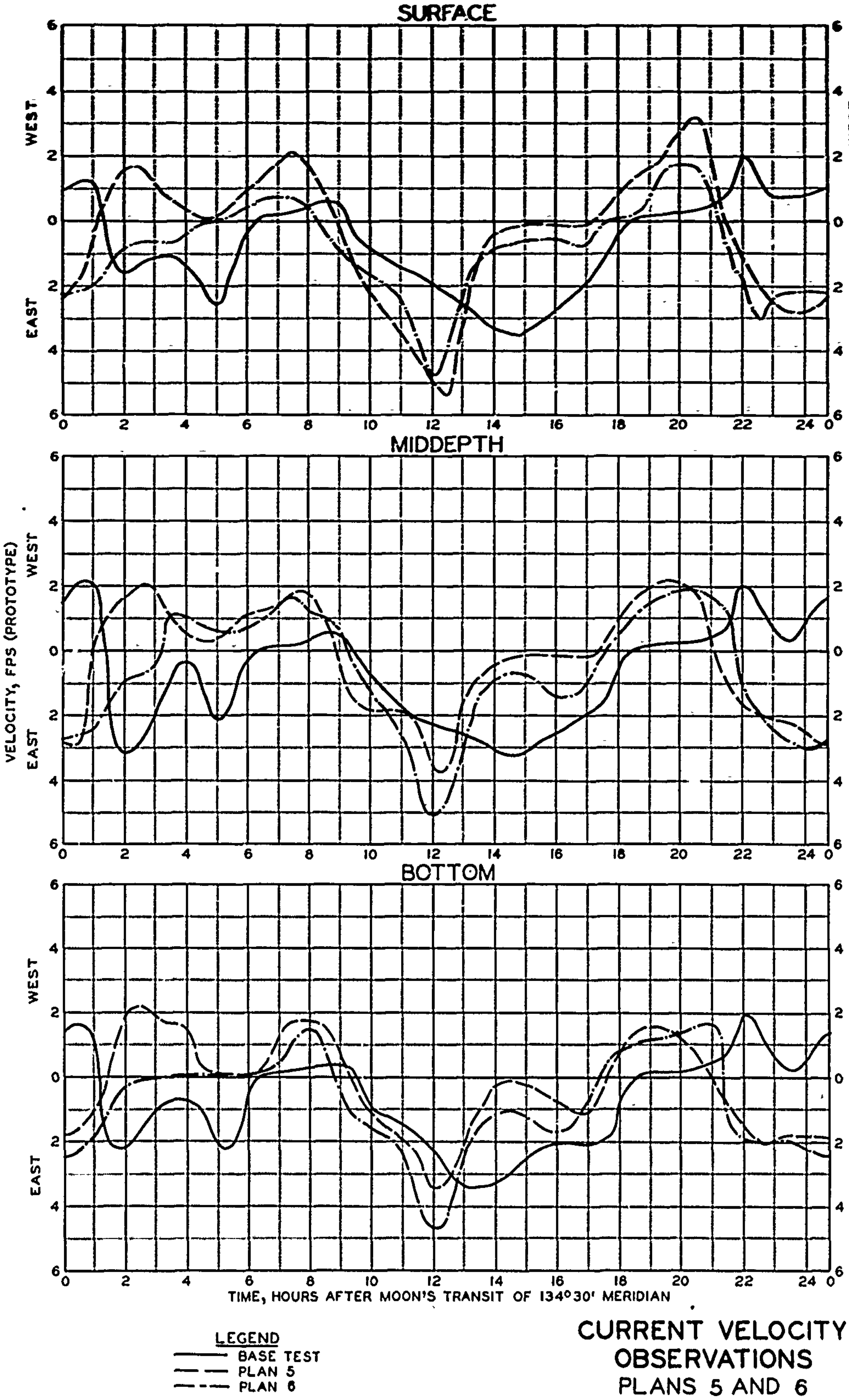
TIDAL OBSERVATIONS
PLANS 5 AND 6
STATION LEMON CREEK
SPRING TIDE



LEGEND
——— BASE TEST
— — PLAN 5
—·— PLAN 6

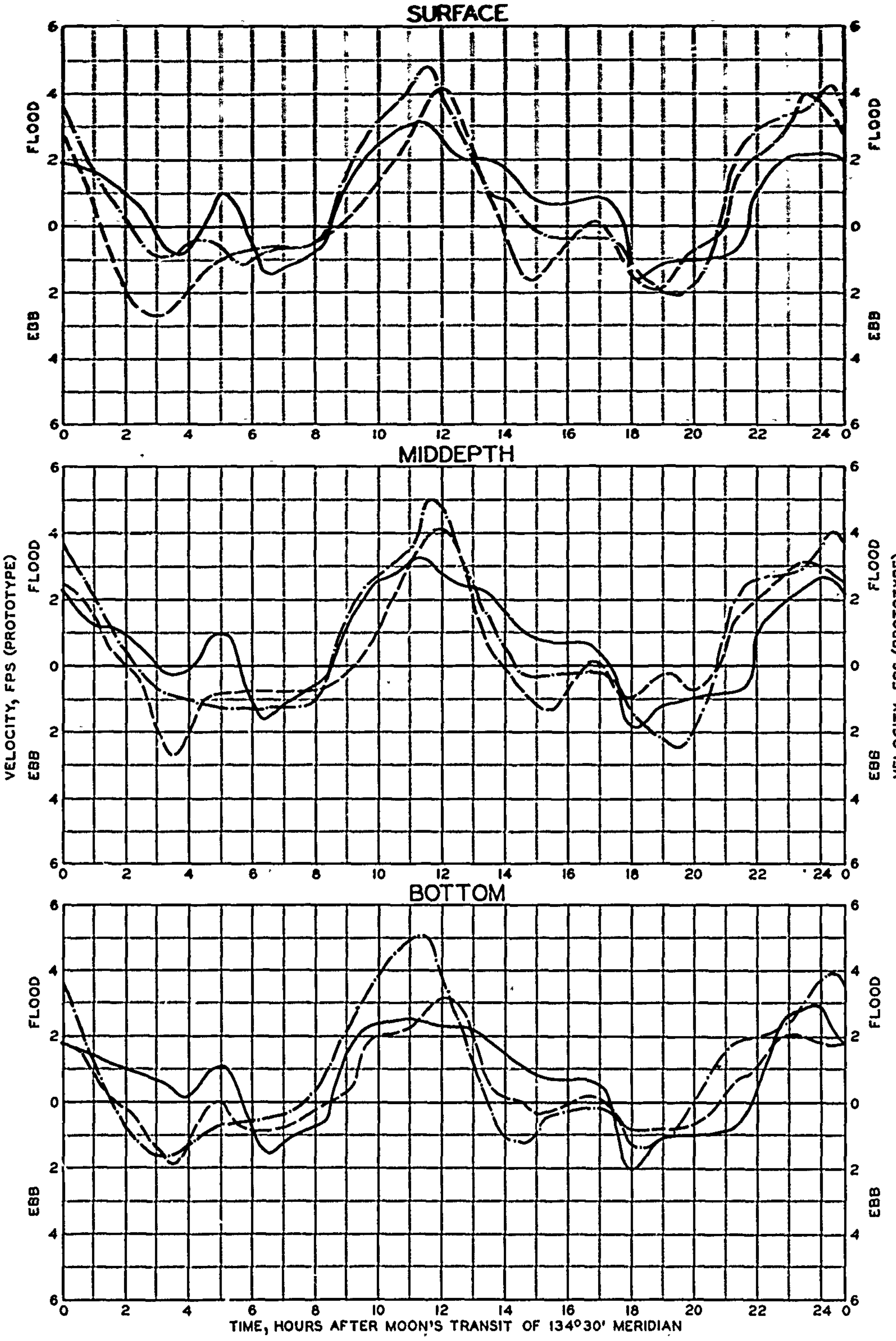
NOTE: EBB IS DIRECTED TOWARD JUNEAU (EAST)

CURRENT VELOCITY OBSERVATIONS
PLANS 5 AND 6
STATION 1
SPRING TIDE



NOTE: EBB IS GENERALLY DIRECTED TOWARD JUNEAU (EAST)

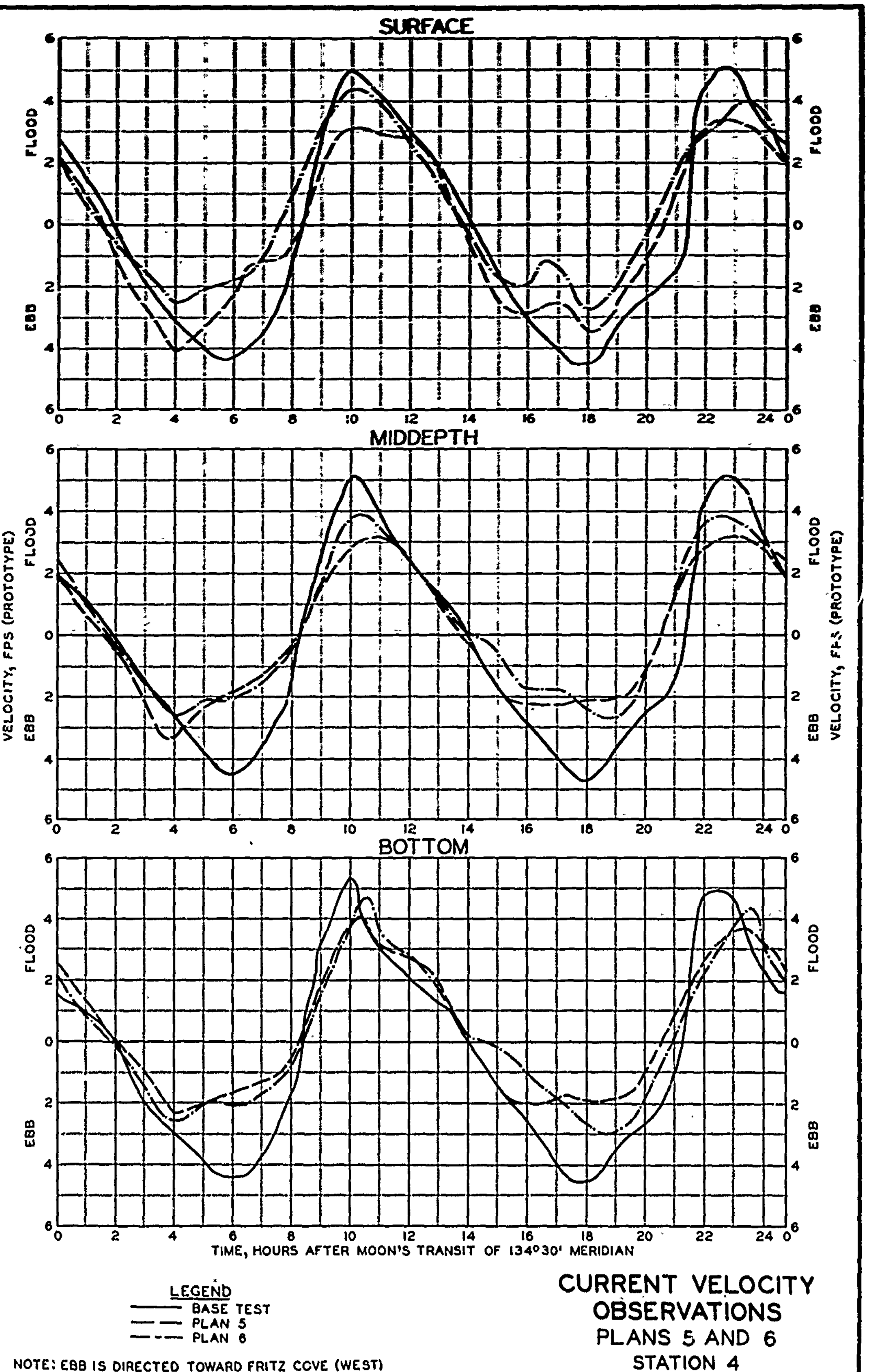
CURRENT VELOCITY OBSERVATIONS
PLANS 5 AND 6
STATION 2
SPRING TIDE



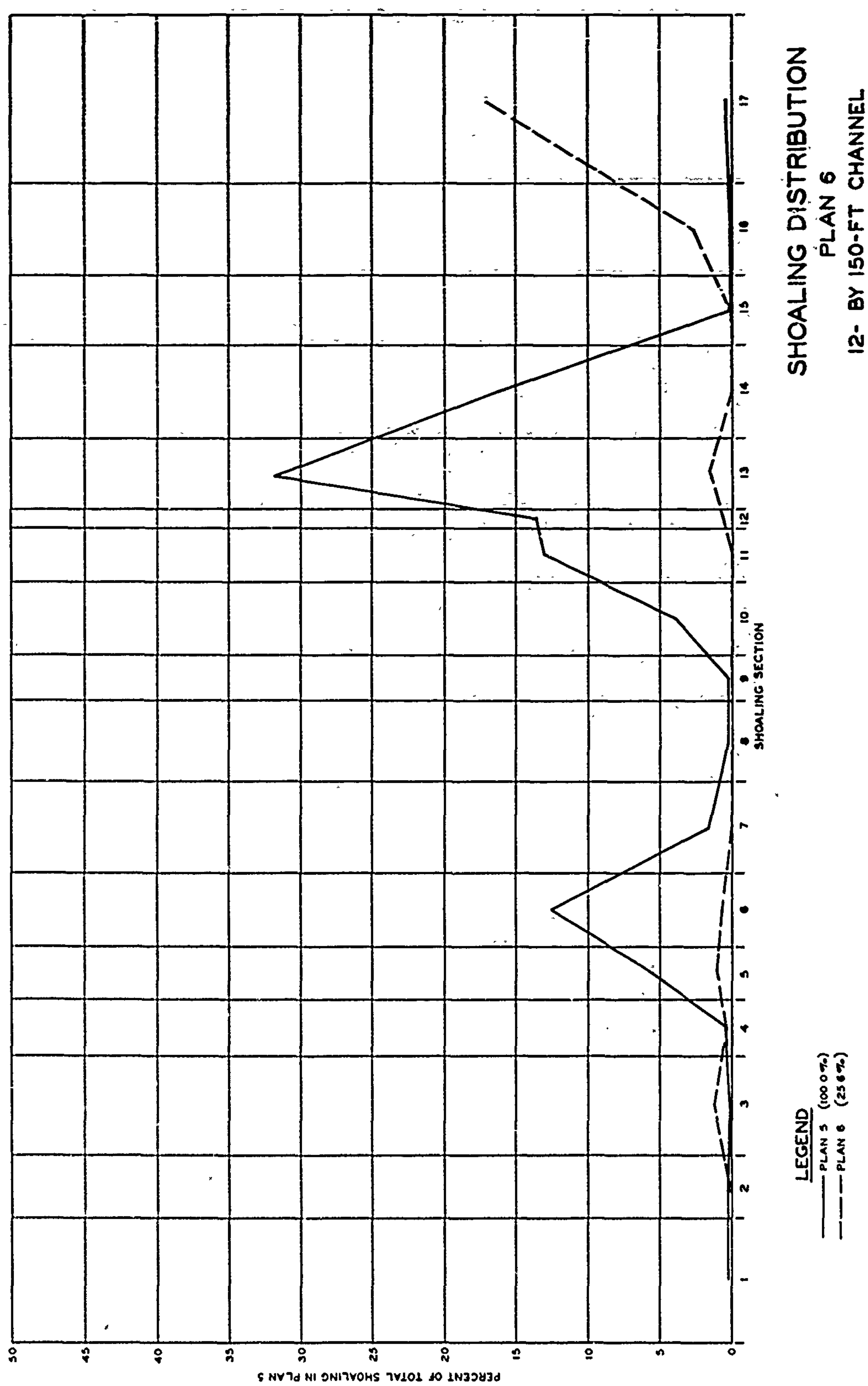
LEGEND
BASE TEST
PLAN 5
PLAN 6

NOTE: EBB IS DIRECTED TOWARD FRITZ COVE (WEST)

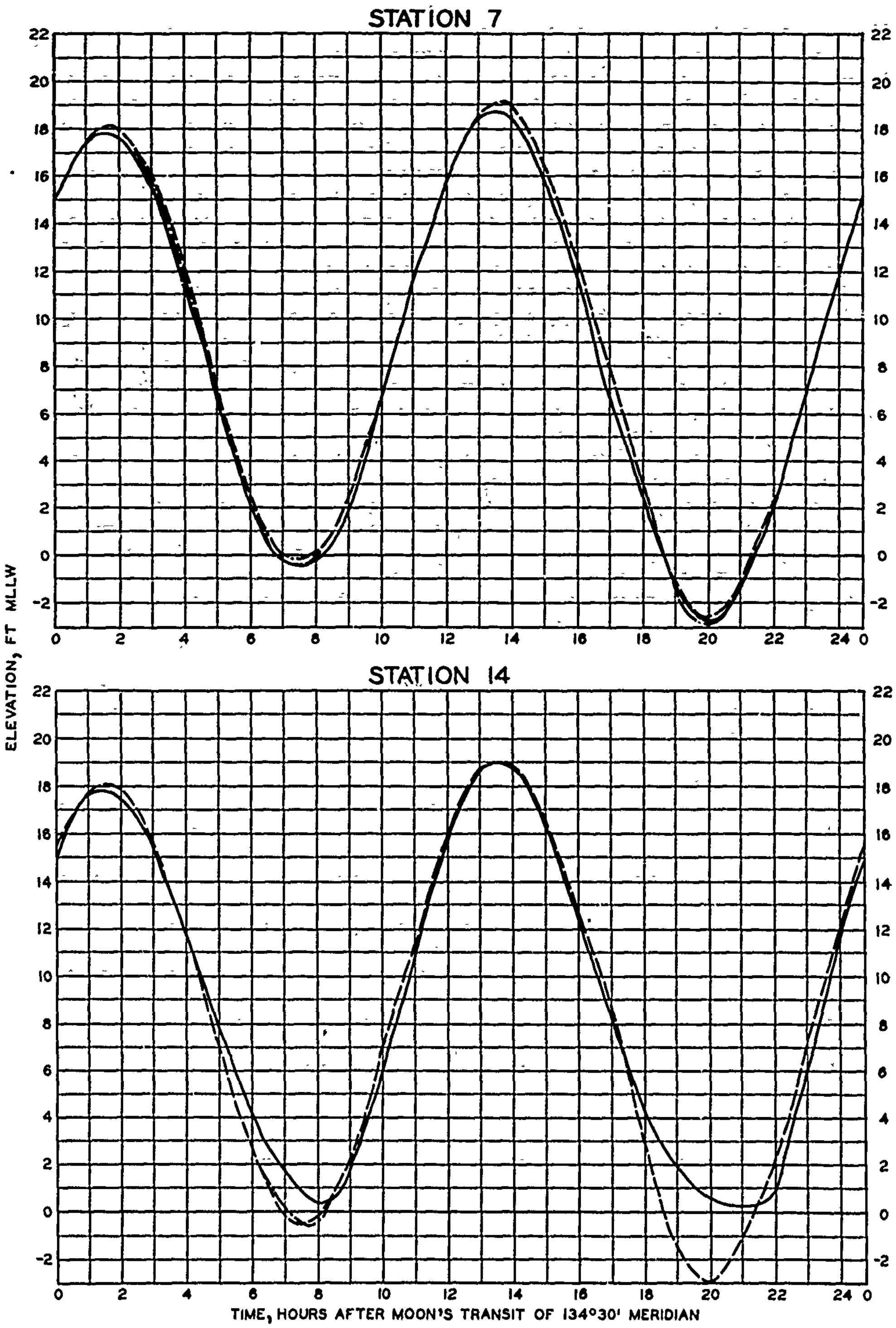
CURRENT VELOCITY OBSERVATIONS
PLANS 5 AND 6
STATION 3
SPRING TIDE



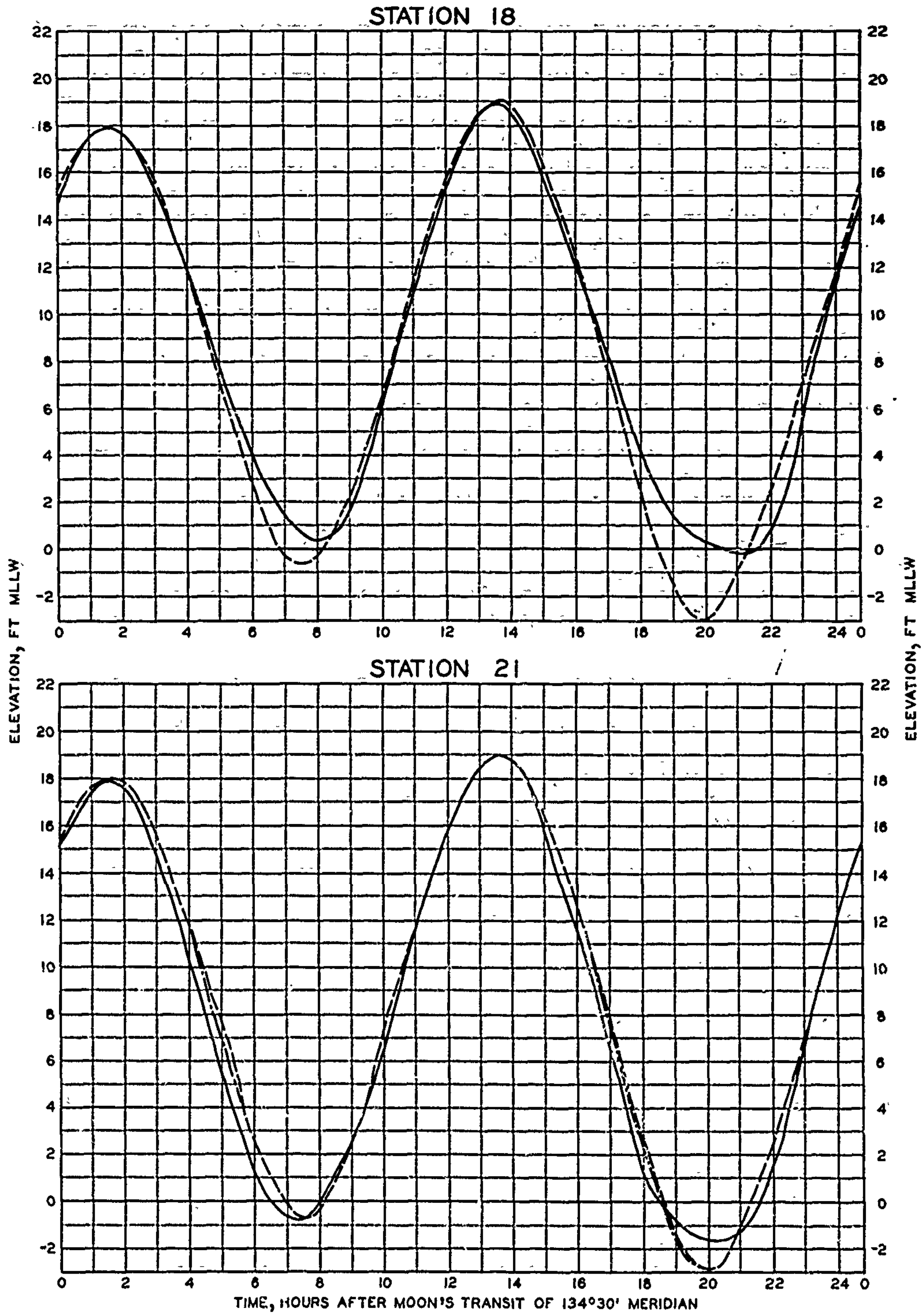
CURRENT VELOCITY OBSERVATIONS
PLANS 5 AND 6
STATION 4
SPRING TIDE



SHOALING DISTRIBUTION
PLAN 6
12- BY 150-FT CHANNEL

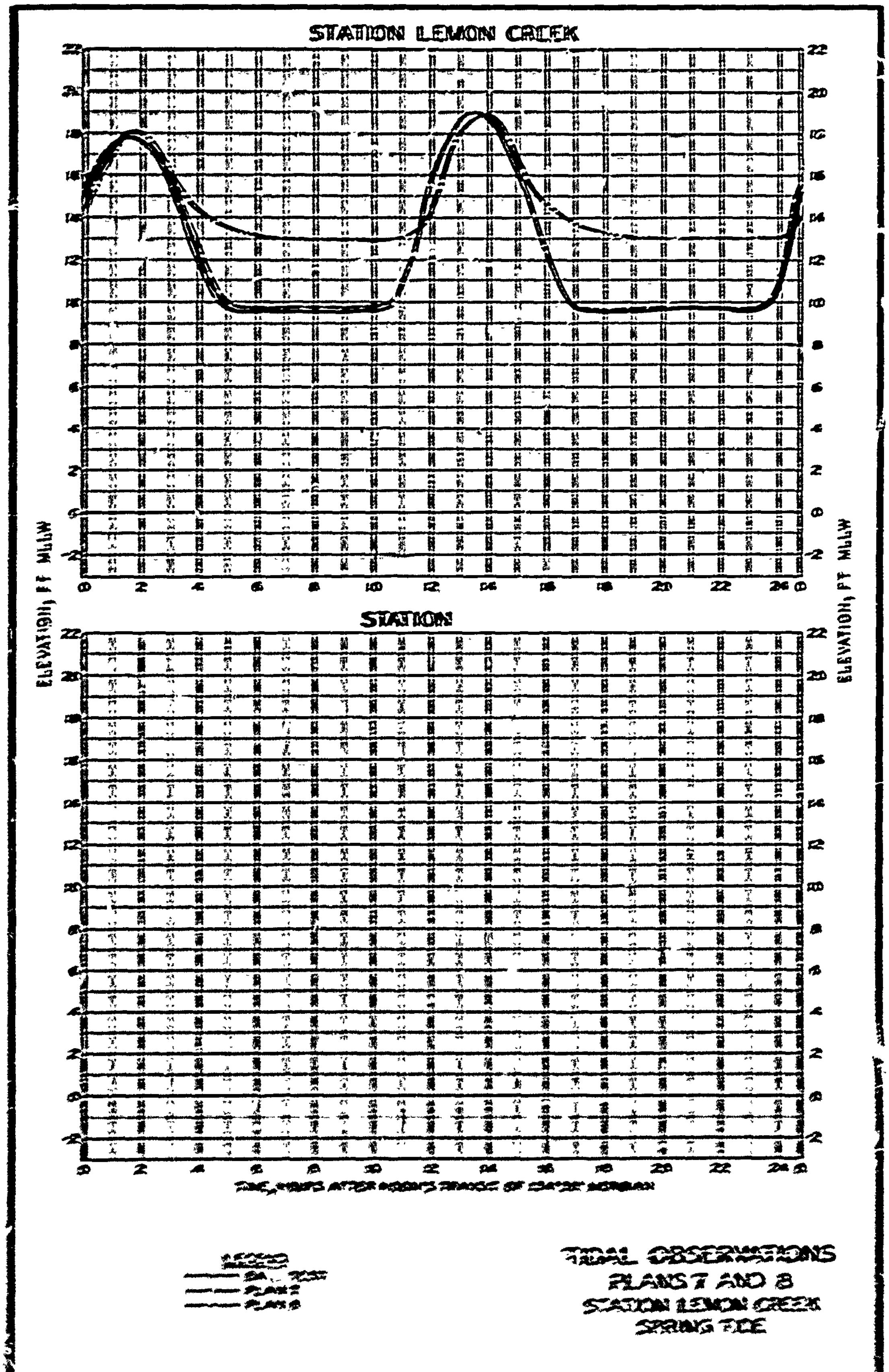


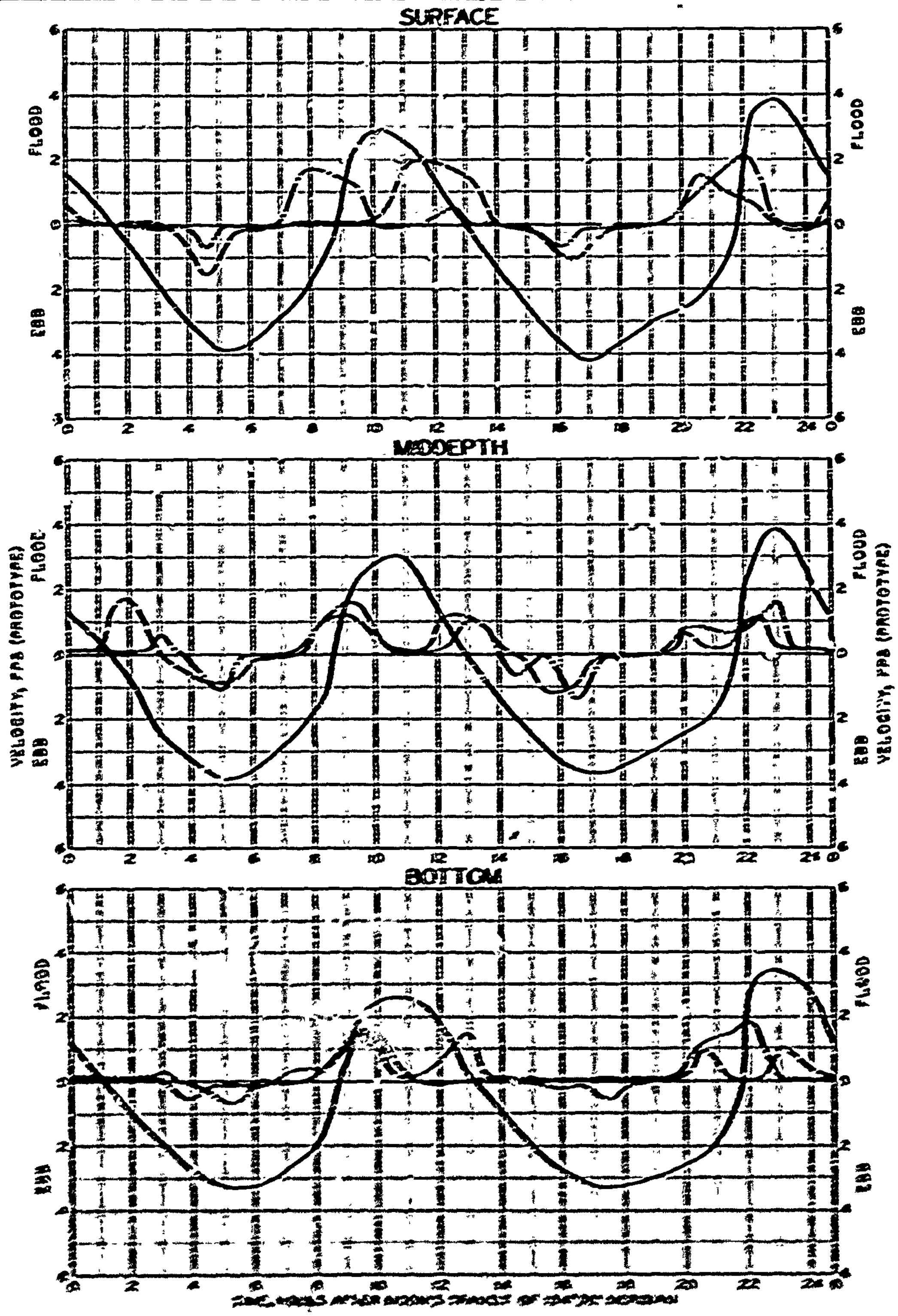
TIDAL OBSERVATIONS
PLANS 7 AND 8
STATIONS 7 AND 14
SPRING TIDE



TIDAL OBSERVATIONS
PLANS 7 AND 8
STATIONS 18 AND 21
SPRING TIDE

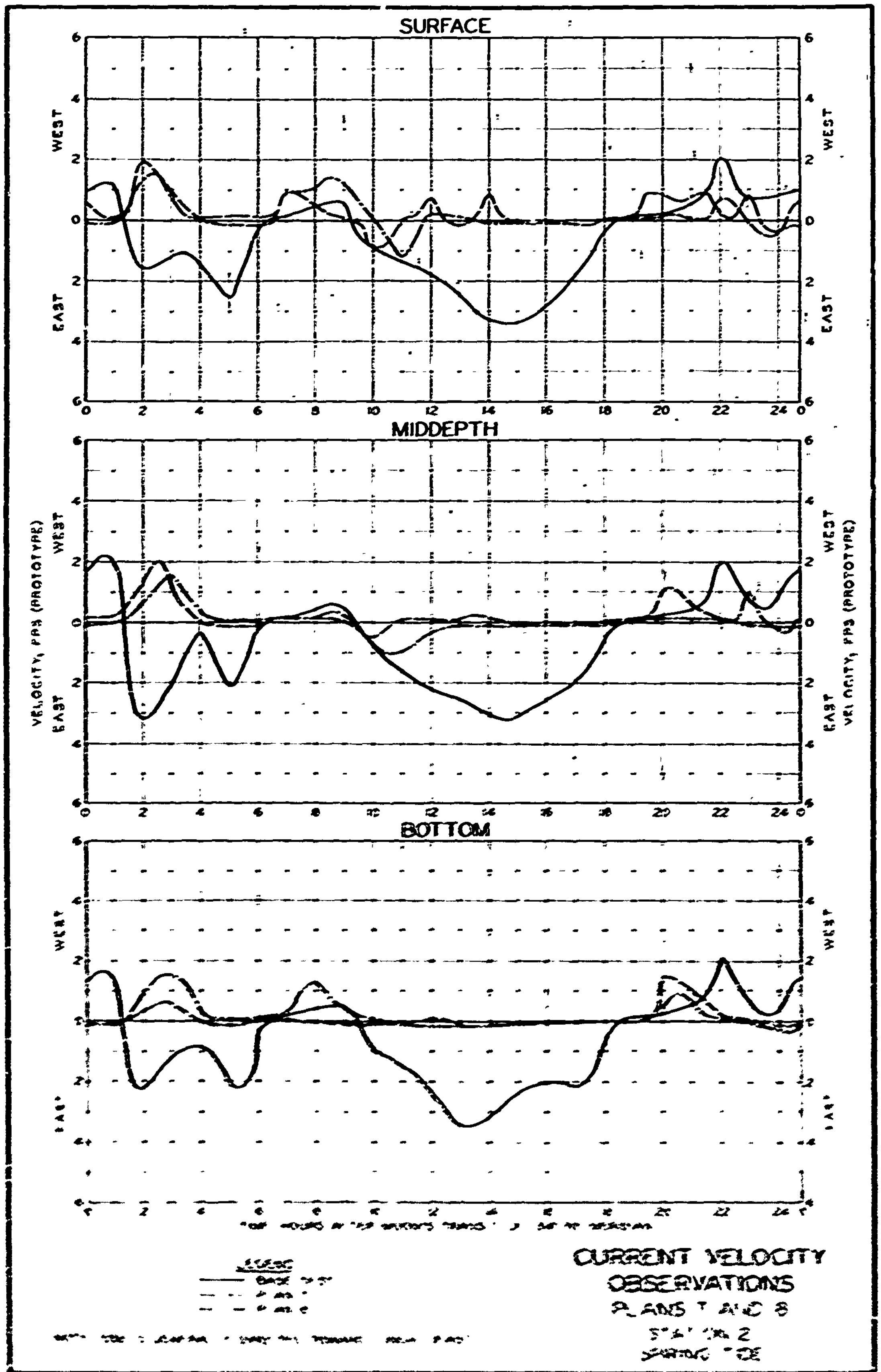
PLATE 43

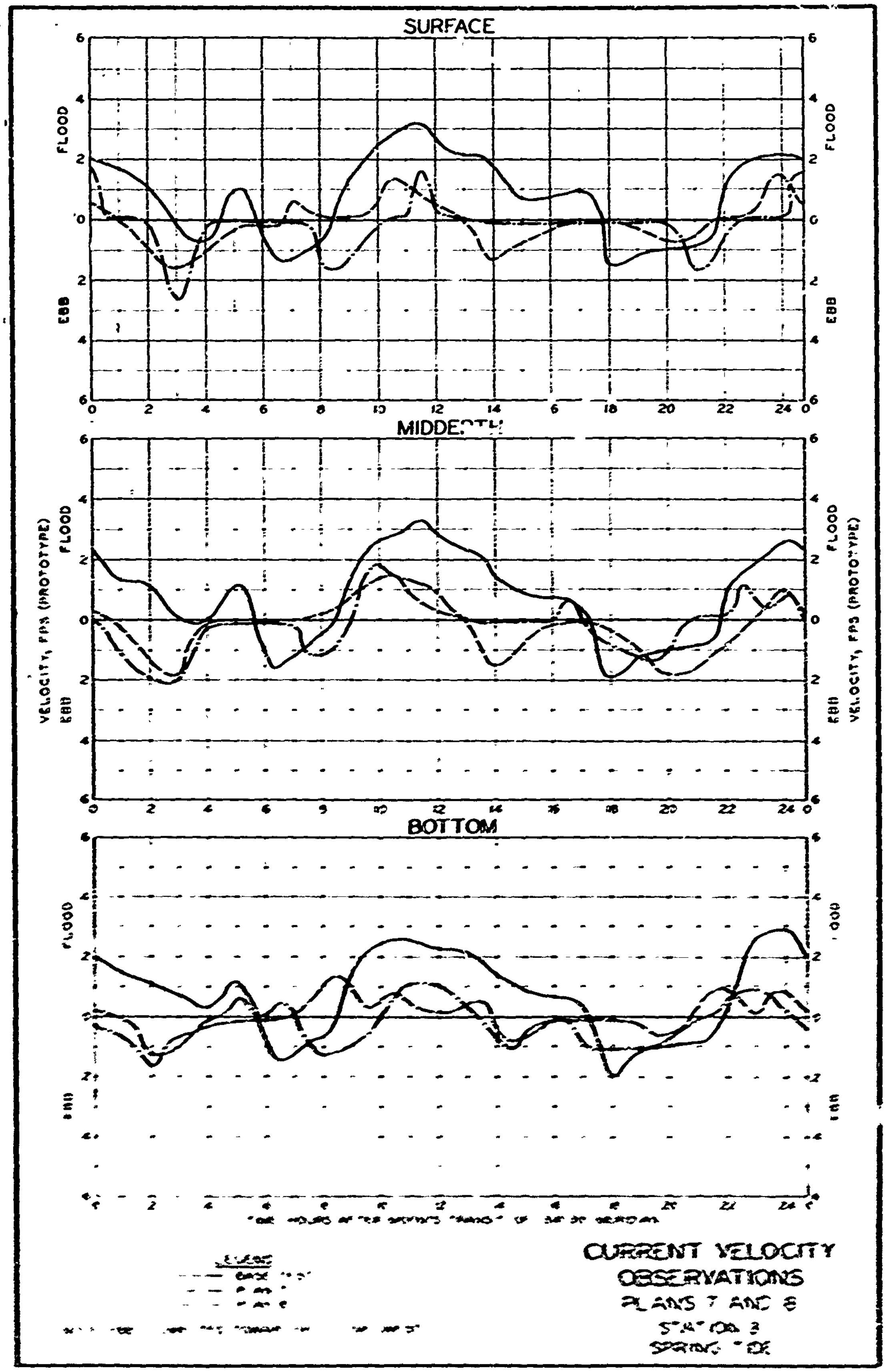

STATION LEMON CREEK
STATION
ELEVATION, FT MLLW
TIDAL OBSERVATIONS
PLANS 7 AND 8
STATION LEMON CREEK
SPRING TIDE



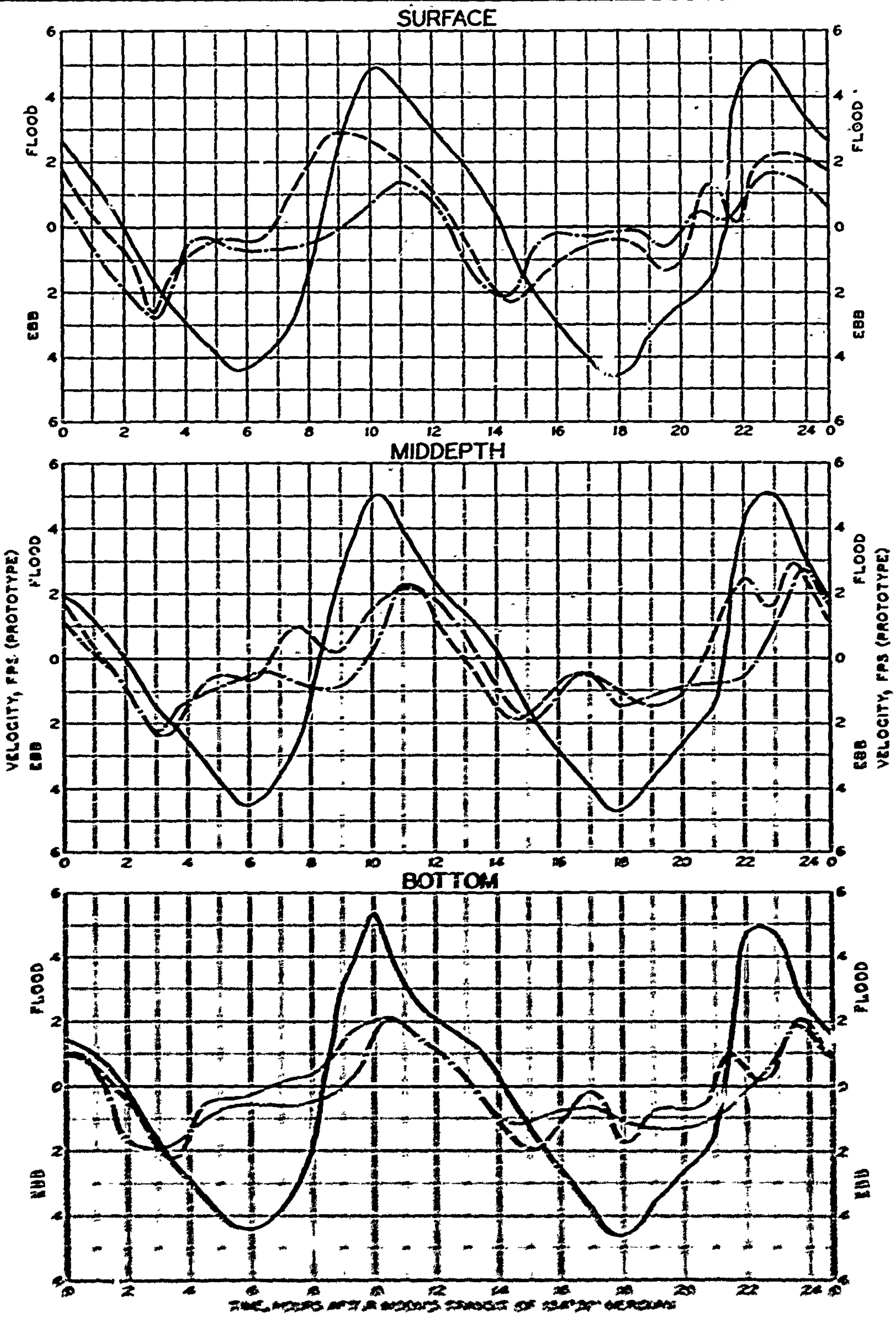
LEGEND
BASE TEST
PLAN 7
PLAN 8

CURRENT VELOCITY
OBSERVATIONS
PLANS 7 AND 8
STATION 1
SPRING TIDE


SURFACE
WEST
EAST
MIDDEPTH
VELOCITY, FPS (PROTOTYPE)
BOTTOM
LEGEND
CURRENT VELOCITY
OBSERVATIONS
STA. NO. 2

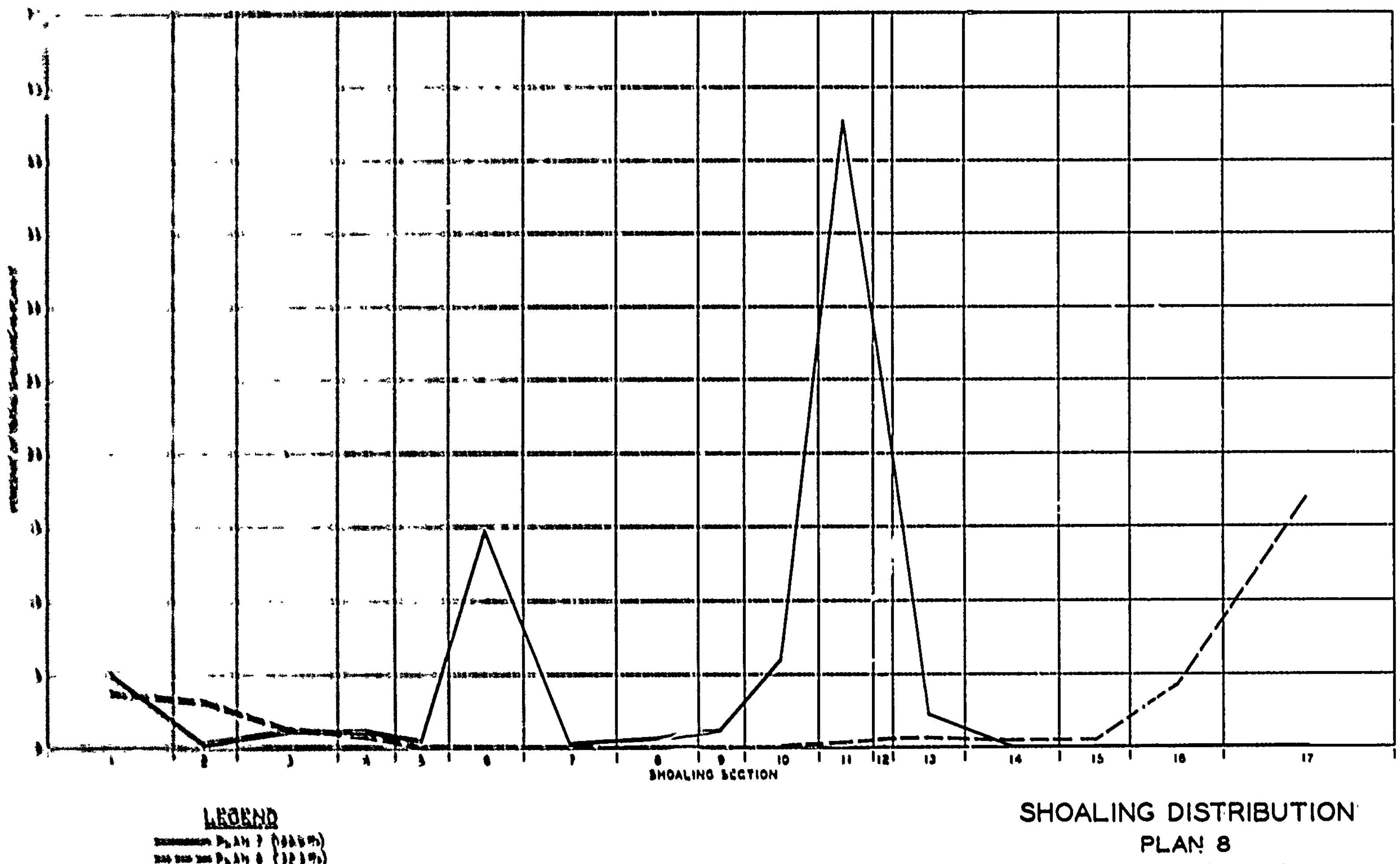


CURRENT VELOCITY
OBSERVATIONS
PLANS 7 AND 8
STATION 3
SPRING TIDE



LEGEND
BASE TEST
PLAN 7
PLAN 8

CURRENT VELOCITY OBSERVATIONS
PLANS 7 AND 8
STATION 4
SPRING TIDE



SHOALING DISTRIBUTION
PLAN 8
30- BY 300-FT CHANNEL